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Contents

	PAGE
The Strength of Steel and Cast Iron (Leader)	51
Founders' Forum	52
Pig-iron Licences	52
Determination of Tin in Cast Iron	52
Random Shots	52
The Strength of Steel and Cast Iron	53
Welded Non-Ferrous Casting Assemblies	55
Some Jobbing Foundry Experiences—I	57
Australian Ironfounders and War Conditions	57
Production of Pressure-Resisting and High-Duty Castings	58
Test-Pieces for Steel Castings	58
Steel Melting in Electric Furnaces	59
Structure of Liquid Metals	60
Pendulum Indentation Hardness Testing Machine	61
Catalogues Received	61
Copper Price Prospects	61
Processing and Surface Treatment of Aluminium Castings	62
Reducing Pattern and Core-Box Maintenance	64
Book Review	64
Canadian Iron Ore	64
The Week's News in Brief	66
Trade Talk	66
Personal	66
Obituary	66
Raw Material Markets	68
Reports and Dividends	68

The Strength of Steel and Cast Iron

From the early days it has been recognised in the strength properties of alloys that these are affected by the proportions of the constituents of the alloy, the conditions of cooling, working in manufacture and heat-treatment. Some proportionality between these causes and effects has made fascinating the attempts to assign numerical values to these respective influences and to design mathematical expressions which will enable strength values to be calculated and predicted. In the realm of steel metallurgy efforts of this kind can be traced back at least as far as 1885 in published literature, and there are many of the older generation of metallurgists who are still familiar with those formulæ for the strength of acid and basic steel propounded by Prof. Campbell in the year 1895. These simple formulæ, linear in form, attempted to include the influence of carbon, phosphorus and manganese, in addition to the conditions of rolling and thickness of the piece. There is a naïve similarity in the reasoning of the late Dr. J. E. Stead and that of Corson in the article produced elsewhere in this issue, although the expression deduced by Stead is simpler in form and more restricted in its range. Speaking of steel, Stead says that "if the carbon is below 0.8 per cent. the steel has segregations of what may be termed tool steel containing about 0.9 per cent. carbon and free iron, and these are quite separate from each other but in juxtaposition. To put in other terms, they are mixtures of steel having a tenacity of about 52 tons per sq. in. and iron having a tenacity of about 20 tons. The tenacity of steels after heating to redness and cooling in air is approximately proportional to the amount of these two bodies. Thus a steel containing 50 per cent. of each has a tenacity of 52 plus 20 divided by 2 tons, equalling 36 tons per sq. in., and one with 25 per cent. of the harder constituent calculated in the same way shows a strength of 28 tons per sq. in." Incidentally this relationship gives results slightly lower than that proposed by Corson. The formula proposed by Corson is of an exponential character and has a wider range of application into the range of hyper-eutectoid steels. From our own special point of view this is capable of extension to cover grey cast irons and malleable cast irons by the use of a coefficient which takes into account the effect of the graphite content in weakening the structure. This coefficient is determined by an empirical formula derived from a statistical study of a number of data for cast iron on the basis as described by Corson.

Our conception of the structure of alloys has undergone and is still undergoing marked changes as a result of the efforts of the physicist and the mathematician due to their greater powers of penetration, both experimental and otherwise. Foundrymen who were privileged to hear the Edward Williams lecture by Prof. Bragg will remember how he showed that the X-ray study of metals and alloys has made it clear that their strength comes, not from bonds between neighbouring metal atoms, but from irregularities of structure. The sheets of atoms in the perfect metal slither over each other quite easily, but must do so in certain directions related to the crystalline structure. If the metal is broken up into crystallites with different directions of easy glide the movement of the sheets of atoms in one crystal interferes with that of its neighbours and the whole structure jams. If foreign atoms are present they set up centres of local disturbance and in a like manner interfere with the easy glide of the sheets of atoms. Although the physicist seems to have clearly established that the strength, toughness and ductility of metals and alloys are due to the ease with which atoms can glide past their neighbours, combined with the jamming effect of imperfections in the structure due to various causes, attempts to reduce this knowledge to a mathematical basis for the calculation of strength values has not yet been very satisfactory. There are numerous theories and suggestions of a tentative character and it seems quite probable that Corson's filament theory when fully explained might differ very little from that of the modern physicist.

The physicist and the mathematician have concentrated their methods of attack on the exploration of the structure of numerous alloy systems, some of them of quite a complex character. Of all these it is probably true to say that none is quite so complex as cast iron, the alloy in which we are so particularly interested. In our view the conception advanced by Corson and more particularly his attempt to find a comprehensive expression for the strength values of the complete range of iron-carbon alloys ought to prove very stimulating to those interested in this fascinating study.

Founders' Forum

Q.—We have received a complaint that in machining a recess in 4-in. dia. grey-iron washers excessive tool wear is being experienced. The analysis of the castings showed T.C 3.6 per cent., C.C trace, Si 2.3, Mn 1.01, S 0.069, and P 0.38 per cent. All castings are annealed and have Brinell hardness ranging between 137 and 146. Fractured castings show no evidence of chill or hard spots. How can tool life be increased, as we can find nothing wrong with metal quality?

A.—Many engineers use expensive milling cutters or special tools having a broad cutting edge for machining recesses or depressions in washers, and the surface condition of the castings plays an important part in obtaining satisfactory tool life. In the majority of cases where metal quality seems satisfactory, tool wear can usually be traced to the presence of sand through improper fettling. When castings are subject to special tooling operations it pays to see that all sand is removed by sand-blasting or shot-blasting. The removal of all sand from the casting surface is of more importance than hardness of the iron. Examples are known of castings having a Brinell hardness numeral of 228, free from surface sand, being milled at production speeds, whilst softer iron having a hardness value of around 150 caused tool failure due to the presence of sand.

Q.—A brassfoundry producing large quantities of small Monel bush castings in green-sand moulds made from Mansfield sand states that the finish on the castings is not all that could be desired, and asks how it can be improved.

A.—In the past many brassfounders making Monel and other nickel alloy castings have used the ordinary green sand available, which is usually one of the red sands, such as Mansfield, Belfast, etc. Whilst sands of this type give a good finish on general brass and bronze work, they are not sufficiently refractory for alloys requiring a high pouring temperature. Greatly improved results so far as surface finish is concerned are obtained by adopting ironfoundry green-sand practice, utilising a percentage of coal dust in the sand. Care must be taken to ensure adequate permeability. A suitable facing sand would be one containing Mansfield red (coarse or medium) 95 per cent., superfine coal dust 5 per cent., and water to suit. This should only be used for facing purposes, and care should be taken to vent well to ensure complete removal of gas from the mould face.

Viscosity of Blast-Furnace Slags

In a Paper in "Stahl und Eisen" on the effect of silica, titanic acid and alumina on the viscosity of an acid synthetic slag and the calculation of the viscosity of acid and basic blast-furnace slags from their chemical composition, K. ENDELL and G. BRINKMANN report that they have observed that with rising silica content an acid synthetic slag becomes progressively more viscous and that when the total silica exceeds 50.4 per cent. the viscosity exceeds the maximum for free flow at 1,400 deg. in the blast furnace. This maximum viscosity value is $\eta = 75$ C.G.S. units. On the other hand, titanic acid lowers the viscosity value, at least up to a content of 17.3 per cent., indicating that no difficulty should be experienced in smelting titaniferous iron ores. Increasing alumina content raises the viscosity and makes the slags progressively shorter; at the same time, the temperature of crystalline precipitation increases with rising alumina value. Discussing these relationships, the authors refer to the behaviour of slags at Corby. A hyperbolic relationship is deduced connecting the coefficient of viscosity and the absolute viscosity at 1,400 deg., both for basic and acid blast-furnace slags. These curves permit the viscosity of the particular slags considered to be deduced for a temperature of 1,400 deg. from the chemical analysis.

Pig-Iron Licences

TIPTON FOUNDRY FINED

The New Garter Foundry (1926), Limited, of Groveland Road, Tipton, was fined £25 and ordered to pay £7 17s. 6d. special costs at Tipton on Tuesday of last week for acquiring pig-iron without a licence from the Ministry of Supply, and they were also ordered to pay 4s. costs on each of three similar charges.

MR. G. J. BALL, for the Director of Public Prosecutions, said that under the Defence Regulations there was an Order controlling the supply and quantity of pig-iron. The company was granted a permit limited to 20 tons for a period from December 6, 1939, to mid-January, 1940, but it was found that the firm had actually booked orders and obtained goods from the Staveley Coal & Iron Company, Limited, and the Stanton Ironworks Company, Limited, to the extent of 140 tons, which was considerably in excess of the permit. The department, said Mr. Ball, looked upon this procedure with disfavour.

MR. J. E. LARKHAM, who pleaded guilty on behalf of the firm, said they had asked for permission to obtain 100 tons, and wrongly assumed that that had been granted for a month's supply. They had not done anything underhand, because since control was established, they had been compelled to send to the Ministry of Supply weekly returns of all goods going into and out of the works, which disclosed their purchases. They had also to state the actual activities of the company.

He further pointed out that the form of permits had since been altered so as to preclude the possibility of error to which the first form lent itself.

The CHAIRMAN (Alderman W. H. Powis) said the magistrates were bound to look upon the offence as a serious one in these days of control. They thought the regulations should have been more carefully heeded.

Determination of Tin in Cast Iron

In the course of an investigation on the effect of tin in cast iron, carried out by the British Cast Iron Research Association on behalf of the International Tin Research and Development Council, difficulties arose in the determination of the tin content of various samples. These difficulties have now been overcome. Low values of tin were traced to the presence of both tin and phosphorus, in varying amounts, in the insoluble residue of graphitic carbon and silicon from the decomposition of the sample in acid.

In the case of phosphoric iron, this residue may contain up to 40 per cent. of the tin in the sample and a variable amount of the phosphorus, depending upon the tin content. The tin in the residue is estimated separately, by igniting, fusing with sodium peroxide and titrating with iodine after reduction with antimony. The procedure for estimating the soluble portion of the tin recommends the solution of the sample in dilute sulphuric acid instead of hydrochloric acid, to avoid the risk of volatilisation. This is followed by oxidation with permanganate to destroy hydrocarbons, precipitation of tin by hydrogen sulphide, separation from molybdenum and copper with ammonium hydroxide and reduction with antimony. Finally, the solution is titrated with iodine in an atmosphere of carbon dioxide. If desired, the solution from the treatment of the insoluble residue may be combined with the solution containing the soluble tin and the total tin determined in one operation.

Random Shots

An enthusiastic foundryman has written objecting to last week's condemnation of the vast number of new words in the foundry vocabulary which end with "ability." "Not only do they end with 'ability' but they should begin with it too," he declares, "for is not ability the keynote of a very trying industry?"

* * *

The derivation of another word, not appertaining but very familiar to all stout foundry-workers, may be of interest. It is the word "booze," which is of American origin, dating back about a hundred years. It springs from the fact that a certain distiller from Philadelphia, one E. C. Booze, ordered his whisky bottles to be made in the shape of log cabins. Thus that distinctive shape became known as the Booze bottle, and the name has stuck ever since. With passage of time, however, the meaning has become attached to the stuff inside the bottle rather than the bottle itself.

* * *

Got his own back . . .

Father had to amuse the youngster whilst mother went to take her turn on duty at the local First-Aid Post. They were getting on happily with a model aeroplane, when a colleague from the works dropped in for a chat. To the youngster's disgust his father got so deeply involved in metallurgical discussion that both he and the aeroplane were neglected. In fact, father had apparently entirely forgotten the existence of his son until he happened to catch him at the chocolate box. Subconsciously he was aware that the youngster had been munching bar after bar. Suddenly awakening to his parental responsibilities, he duly delivered the necessary reprimand for such wartime greed.

"Well," retorted young hopeful, "I had to take a second piece. The first was in the nature of a test-bar!"

* * *

It is now no longer considered correct to use the good old-fashioned rejoinder "the penny's dropped." In order to keep in line with new values one must say that "the three-ha'pence has dropped!"

* * *

A new definition of a pessimist is the man who, still trying at daybreak to get to sleep after a very early morning air raid, said: "And then the birds had the cheek to start singing!" The optimist would have found comfort in the seeming imperturbability of Nature in spite of human frightfulness.

* * *

Two friends, working seven days a week on munitions, were discussing over a pint what they would like to do after the war is over.

"I'm going to get away from all this din and dirt, and go to live in the country. I'd like to keep a little pub," said one.

Replied the other: "I would like to live in the country, too, but I'd always thought of a pub keeping me!"

"MARKSMAN."

Five-Roomed House—4 Tons of Iron and Steel

According to Penton's Almanac, a typical American five-roomed house requires nearly 4 tons of iron and steel products in its construction, excluding such fitments as the stove, refrigerator, and the like. Steel and iron required for other purposes, including pipes for water and heating, bathroom furnishings, conduit, furnace, radiators, etc., average as follows (weight in lbs.):—Cast iron, 4,250; steel nails, 400; light structural shapes, 65; black sheets, 1,205; galvanised sheets, 725; conduit, 175; miscellaneous steel, 60, and W.I. pipe, 950.

The Strength of Steel and Cast Iron*

By M. G. CORSON (Consulting Metallurgist, New York)

The various tests that combine to indicate the mechanical characteristics of steel are increasing in number, although a particular test may now and then fall into disuse. Not so long ago endurance tests were particularly popular, but their glory was short-lived. Later came the damping and creep tests, which still seem to occupy a very prominent position.

No doubt each of these tests served or serves a useful purpose. Each has contributed to the growth of metallurgical science—although most of them appear destined to be merely additional tools of research, used now and then.

The oldest of all tests, however—that for the ultimate tensile strength—still occupies the first place. Not only is the tensile test rapid and inexpensive, but it is the only test that produces a precise physical value which cannot be misunderstood. Moreover, it is connected by some still obscure law to the true cohesion forces that operate in metals.

The tensile test is capable of yielding six figures directly measurable. Two of these, the proportionality limit, and the " proof stress," are used but rarely. Two others, the yield point and area reduction, are not particularly precise. The last two, the ultimate strength and the corresponding elongation, are always used, and of these the ultimate strength is beyond doubt the most important. Besides, the value does not depend much upon the size of the test-bar. The European bar, 100 mm. long and 10 mm. in diameter, yields values which differ from the ones obtained on the American bar by less than normal deviation.

In view of the accurate values obtained for ultimate strength, the question is often asked as to the value of ultimate strength that must be expected for a sample of steel for which the composition and recent history are well known, and, most naturally, in view of the great practical importance of steels that simply are hot-rolled and air-cooled, it is essential to know their tensile strength in precisely such a state. The question as to the maximum strength of a given steel after the brittleness due to the presence of martensite is just removed is also interesting. However, this latter question is asked but rarely.

Factors Influencing Strength

The usual commercial hot-rolled steel contains, in addition to a prescribed amount of carbon, various but always small amounts of phosphorus, silicon and manganese.

The variations in these three are not so easy to control, but essentially the limits are quite narrow and the analysis depends specifically upon the process used in melting, *i.e.*, whether acid or basic.

Doubtless these small amounts of phosphorus, silicon and manganese either stay in solid solution or form inclusions. The latter influence most specifically the ductility of a given steel. The parts retained in solid solution, however, may have an influence upon the tensile strength. Unfortunately, there are still no precise data available concerning this influence. Of course, it might seem very easy to produce a number of steels in which only one element would vary, but the truth is that it would be very difficult. Laboratory tests made upon steels melted in an electric furnace may have but little in common with results in open-hearth practice. Besides, the study of the simultaneous influences of four elements (carbon, phosphorus, silicon and manganese) would call for at least 625 heats plus, in all probability, the same number of repeat and check heats. Of course, the difficulties are not unsurmountable, and some day in the not too far distant future a thorough programme of such research may materialise. However, so far, there is comparatively little detailed evidence for the action of the three minor elements.

Various assumptions made on this action during the past 20 years or so have not always coincided, and certain beliefs are definitely exaggerated. So, it is assumed quite frequently, that a point of phosphorus raises the strength of steel uniformly by 1,000 lbs. per sq. in. Analogously, the effect of silicon is estimated variously—from 150 to 340 lbs. per sq. in. strength increase per point.

That these figures are greatly exaggerated can be deduced from the magnitude of various effects when an additional element is dissolved in copper or some other metal. Silicon is a very potent strengthener for copper, and when added up to 2 per cent., it raises the ultimate strength from 14 tons almost uniformly up to 24.6 tons per sq. in. This is at the average rate of 115 lbs. per sq. in. per point. Other elements entering into solid solution have even less effect per point. So, making all due allowances, it should not be expected that any element staying in solid solution in the matrix of steel might raise its strength by over 250 lbs. per sq. in. per point. This would mean that a carbon-free steel might possibly be about 4,000 lbs. per sq. in. stronger than pure iron. The matrix may have a value of 18.7 tons per sq. in., but probably does not reach such a figure.

Effects of Carbon

Carbon certainly has far stronger effect per point, because its state in steel is quite different. For it is hardly likely that even 0.01 per cent. carbon will remain dissolved in the ferritic matrix of a low-carbon steel. The question is what this specific state might be.

Certain typical structural features are associated with the state of carbon. It suffices to list martensite, troostite, sorbite, pearlite, spheroidised carbide and ferrite. The first essentially signifies a simultaneous occurrence of the highest hardness and brittleness. The others are associated with various levels of strength, with troostite belonging to the highest level. In addition, there has never been any lack of attempts to introduce new structural terms like osmondite, troosto-sorbite, etc.

Of the structures mentioned, only sorbite and spheroidised carbide are mechanically uniform. Thus, it might be stated that such a steel is so-and-so strong because it is sorbitic. Pearlite occupies separate fields except in nearly eutectoidal steels. A steel with 25 points of carbon has just about 30 per cent. of pearlite in separate nests. A fracture might easily pass through a strictly ferritic field so that the presence of pearlite would have but little hardening effect.

It is the theory of the author that all these beautiful structural characteristics and their still more beautiful names are merely companions of the different levels of strength—not their causes. A steel is troostitic because at a given strength it tends to possess as well a large number of troostitic nodules—not *vice versa*.

According to this theory, every carbon alloy of iron is precipitation hardened even if it is subjected to a spheroidising anneal for days. Only that precipitate of carbides which remains invisible accounts for the additional strength, and any specific state of steel is characterised by the amount of carbides still remaining in the ultramicroscopic state.

In other words, what is perceived on looking upon something which may be called troostite are merely the products of destruction of the true structure of steel. A localised accumulation of fine breakage is troostite. A rough breakage arranged in well-organised heaps is pearlite, etc. The true structural frame of the building that remains intact is still quite invisible.

Particles or Filaments?

The first theory of precipitation hardening explained the action as being due to the presence of a large number of key particles interfering with slip. That, of course, is a suggestion that could not be peremptorily excluded. However, it must be stated that there is nothing in nature that could be used as an analogy on a magnified scale.

Quite different is the situation if it is assumed that the precipitated hardener—in the case propounded herein, carbide—forms filaments. Nature and human art present a number of analogies of this kind.

Reinforced Concrete Example

One such case can be seen in reinforced concrete structures. Here, a mixture of cement with fine sand and water forms the matrix of concrete. The heavy gravel used for ballast can be compared to pearlite, spheroidised carbide and various inclusions. The strength is due essentially to the wires and strips of iron which are imbedded in the matrix.

Suppose a steel is visualised with filaments of carbide 10 times thinner than can be discerned under a microscope. Such a diameter would be about 0.0000004 in. Suppose it could be magnified one million times. Then each filament will look like a rod 0.4 in. thick—a frequent size in reinforced concrete structures. On the other hand, a particle of pearlite 0.0004 in. long and 0.0001 in. thick would look like a slab of stone 40 in. long and 10 in. thick. Certainly, the usual concrete might be regarded as a model of refinement in comparison.

In the ponds of the Eastern States there may be observed certain strange oval masses of a transparent jelly-like substance weighing up to 30 lbs. and surrounding a stem of pickerel grass. Such masses result from the labour of a few generations of a tiny organism Pectinatella or moss animalculi. Not very strong, they are still strong enough to be cut into cubes which do not change their shape under the force of gravity.

These masses are built of 99.65 per cent. water, 0.10 per cent. of mineral substance that was dissolved in that water and only 0.25 per cent. of an organic material. The high transparency of the whole structure—about 10 in. thick—indicates that the jelly-like mass is built of a network of fine fibres with all the water being carried in the interstices. No particles would form a solid mass when added in the amount of 0.25 per cent. to water and no structure of films, no matter how thin, would leave the mass as transparent as it is.

Such are the examples from art and nature. Another argument for the filament structure can be based on the principle of strain release.

Any solid solution stands under strain, this being at a minimum at the moment of formation from the molten state, but continuously increasing on cooling. If the strain becomes too great, the solid solution breaks down and precipitates the material added. The larger the visible particle precipitated, the more complete the release from strain. That is why an air-cooled steel will have its carbide in the pearlitic state and an over-annealed sorbitic steel will form spheroidised carbide.

It is not so, however, with the ultramicroscopic particle. Only certain sizes running by stages can be accommodated with a minimum strain. Others would produce strains stronger than were present in solid solution. So, only a few minimum sizes form under a given set of conditions.

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* Reproduced from "The Iron Age" by courtesy of the Editor.

Once a given minimum grain size is reached in one or two directions at one point, it is easier for the particle to grow in one direction almost across the whole grain than for other particles of the proper size to form in the proper places. Thus, a filament structure or plate structure are most likely to form. Plates would affect ductility, but filaments would increase the strength.

Mechanism of Anneal

To explain the softening of hardened alloys (and steels) on annealing, the theory of particle precipitation must assume that some particles get dissolved and others built up, until they are no longer efficient as keys between slip-planes. For many reasons a process of this kind would be hard to realise.

On the other hand, a filament needs only to break up in smaller sections, each section coalescing, in order to develop a minimum surface. It is particularly clear that filaments are quite likely to produce a pearlitic structure if the coalescence stops short of producing a quasi-spherical particle.

It is the author's opinion that the precipitation is most likely to result in an array (not necessarily a network) of filaments of the hardener. In certain cases the amount of such filaments can be controlled by proper heat-treatment. In many others, the material develops an auto-control of a rather precise nature. That is why the strengths of hot-rolled and air-cooled steels containing a given amount of carbon vary by less than 3 per cent. An analogous situation exists when cold-rolled steels are annealed in a regular manner or when certain alloy steels air-harden with surprisingly uniform results.

The Strength Formulæ

To compute the results to be expected, various investigators have offered their empirical formulæ. Quite naturally, the first tendency is always to find a simple proportionality factor. Then it was found that a proportionality law refuses to work and somewhat more complicated formulæ were offered in which the carbon content enters in the square power. Such are the parabolic formulæ.

Later on it has been found important to account in the formula for the well-known effects of manganese, which in the light of the present theory amount simply to an increased preservation of the carbide filaments. These formulæ are composed of a number of terms, one of which carries the product of the manganese and carbon contents.

Nevertheless, all these formulæ are strictly empirical. Of course, all formulæ must be empirical, *i.e.*, based upon the study of practical data. However, empirical formulæ may and may not have a logical foundation, and the formulæ now in use do not. Then, again, formulæ may be applicable to a wide range or to a narrow one—the present-day formulæ are narrow. They fail completely before the carbon content reaches 0.6 per cent.

There is, however, a mathematical expression which is logical and has a wide range of application. To present the basic idea, consider the following case.

A manufacturer possesses a number of well-equipped units each requiring the labour of an organised team. This team working without disturbances has a certain maximum efficiency, but take two teams and put them in one room, and the efficiency of each will fall. Put in three and the efficiency will fall still more. However, a higher total production will be obtained from two, though less efficient, teams, or three still less efficient teams, etc. For a time the total production will continue increasing in spite of the lowered efficiency. Then it will start decreasing.

This situation can be presented by the formula:

$$\text{Production} = NCe^{-bN}$$

Here N is the total number of teams, C corresponds to the scale of accounting for the production, and e^{-b} the efficiency of one team.

In the same manner, a molecule of iron carbide can be considered as the team of four workers (Fe_3C). The efficiency of each team will drop when other teams are added, but the total production of strength will continue increasing—up to a maximum point.

The factors C and b vary from one situation to another. Sorbitic steels tempered at 400 deg. C. after being oil-quenched will require factors different from those valid for a water-quenched troostitic steel or for cold-rolled and annealed stock. It suffices, however, to determine the factors for two well-chosen samples of different carbon content, but of the same content (approximately) of manganese, silicon and phosphorus and of the same history, to obtain a formula which will be correct within 3 to 5 per cent. for any amount of carbon present.

The author has applied this principle to a large number of published data on cold-rolled and annealed steels. Assuming the strength of the matrix to be 24.1 tons per sq. in., the additional strength has been computed as being represented by the formula:

$$S = C\ (162)\ e^{-0.8C}(1{,}000) \times$$

C is in per cent. Using this formula, the following set of strength/carbon content data are obtained:—0.1 per cent., 25.3; 0.2 per cent., 29.3; 0.3 per cent., 34.0; 0.4 per cent., 38.0; 0.5 per cent., 41.2; 0.6 per cent., 44.1; 0.7 per cent., 46.2; 0.8 per cent., 41.2; 0.9 per cent., 48.7; 1.0 per cent., 49.6; 1.25 per cent., 50.3; 2.0 per cent., 46.5 tons per sq. in.

It can be seen from these figures that a normally annealed plain carbon steel will reach a maximum of 50.3 tons per sq. in. strength at 1.25 per cent. carbon, but the gain will be quite immaterial after the steel passes the eutectoid point. In fact, no worthwhile increase in strength will take place beyond 0.8 per cent. carbon.

On the other hand, beyond 1.25 per cent. carbon there will be a slow decrease in strength, and at 2 per cent. carbon no more than 46.5 tons per sq. in. could be expected.

Strength of Grey Iron

As in steel, the usual constituents—carbides, pearlite, ferrite and different inclusions—will be found in grey iron. Now and then there will be patches of sorbite. Beyond all this visible picture there will be the invisible structure of reinforcing filaments of carbides, and in the foreground will be seen the flakes of graphite.

The matrix of cast iron could be considered essentially as cast steel. The flakes of graphite, gas porosity and inclusions would represent the weakening factors.

Contrary to many an opinion, cast iron is not likely to be porous unless very poor materials and bad technique are used. The specific gravity of an average cast iron will not differ from the figure computed on the basis of analytical data by as much as 3 per cent.

Thus, in view of the presence of the large weakening effects of graphite, the weakening due to porosity might be eliminated as being of a minor importance. Moreover, for a cast steel devoid of porosity, there is justification to expect an almost full strength of the same steel in the rolled and annealed condition.

Again, there is no need to be troubled by the presence of phosphides, sulphides and mineral inclusions. They may be bad for ductility or hot working characteristics, but they will hardly affect the strength by more than their volume percentage—assuming them to be voids. Their total volume does not go beyond 1.5 per cent.

Consequently the problem reduces itself to the very simple question: What is the weakening effect of the graphite present? The graphite is present essentially in the shape of flakes. These flakes may vary as to their surface and thickness, and they may form various combinations and designs. These combinations are most likely to strike the eye, and there may be an inclination to start classifying the shapes that occur. The so-called rosettes might be given specific attention.

However, a rosette is not likely to be more than 0.03 in. across, or about 0.0009 sq. in. in area. The test-bar will have an area of over 0.5000 sq. in. Put fully one hundred rosettes in every cross-section and no other flakes of graphite beside them, and the section will be reduced by 18 per cent. The strength—in the case of 0.6 per cent. combined carbon—will be around 36.6 tons per sq. in. Will not it be too good?

So, it is not the shape of the incidental ensemble that will affect the strength of the cast iron. It will be stronger or weaker according to the amount and size of the individual flake.

A Probability Problem

Suppose the graphite flakes to be quite uniformly distributed and always standing perpendicularly to the cross-section of the test-bar. The loosest cast iron contains about 10 per cent. graphite by volume. Therefore, these flakes will cut the section's active area by not over 10 per cent. or so. It would be a mighty strong cast iron indeed.

Now suppose the same flakes to run only in the direction parallel to the cross-section. Then it will be quite impossible to escape the chance that here or there a section will run exclusively through graphite. The casting will have no strength whatsoever.

How will the flakes of graphite be distributed in a real casting? This question cannot yet be answered because too little work has been done in the statistical studies of grey iron structures. It can be said, however, that on purely theoretical reasons the probability of a bad distribution increases greatly when the average flake becomes too wide and too thin. A short and thick flake (average estimated from microscopical study) means a strong iron, very "fine" (thin) flakes indicate a weak one.

The author is not ready yet to offer a logical formula in which the efficiency of weakening might be represented as analogously as the efficiency of hardening in steel. On the basis of a number of data studied there has been produced the following empirical formula:—

$$\text{Per cent. weakening} = 68 - 1.05\,R + 0.009\,R^2 - 0.000029\,R^3 + \frac{1330 - 400\,GR}{41.5 + GR}$$

Here R is the ratio of the length to the thickness of the average flake of graphite, while GR represents the analytical figure (percentage) or graphitic carbon. To use the formula the strength of the matrix must be computed first from the content of the combined carbon. Then, the strength of the matrix should be multiplied by the value of the above formula to obtain the maximum possible strength of the cast iron. If R = 1, the formula then becomes valid for malleable cast iron.

Hard-Alloy Wrench Inserts

In the United States, wrench inserts are now being cast of cobalt-chromium-tungsten alloys in order to give them longer life, according to Haynes Stellite Company, Kokomo, Ind.

Electronic Interpretation of Alloying

A consideration of the effect of the electronic configuration of an alloying element on the polymorphic transformation of iron leads H. SCHLECHTWEG in a Paper in "Technische Mitteilungen Krupp (Forschungsberichte)" to the conclusion that elements which contain only *s* electrons in the outer orbit and only *s* and *p* electrons in the first inner orbit are insoluble in iron and hence do not form alloys.

Welded Non-Ferrous Casting Assemblies*

DEVELOPMENTS IN SOUTH WALES

By Wm. WILLIAMS†

White-Metalling Bearings

It is the object of this Paper to describe and illustrate a few simple and more complicated jobs, and to refer to some examples of welding or burning.

In Fig. 1 is illustrated a method for white-metalling a bearing where a flange is required at both ends for taking the thrust of the operating shafting, or maybe for an axle of some kind. The thickness of the metal on the crown is determined by the nailed-on wooden pieces. This part is made in the form of a frame. The bearing is cleaned, tinned and heated sufficiently for the metal to run freely. The bearing is then placed on a board, bearing side down, the frame is put in position, and the inside of the frame is rammed up with sand. The excess is struck off, the mould is turned over and cleaned out. The tinned core is then placed in position, weighted down, and the runner is formed as is shown in Fig. 1. It is about ½ in. higher on one side to allow for an overflow on the opposite side to permit the metal to run through until the required condition is realised. Should the metal remain unduly liquid, it will be necessary to keep feeding until it has solidified. The temperature should be carefully controlled and very particular attention paid to the alloy.

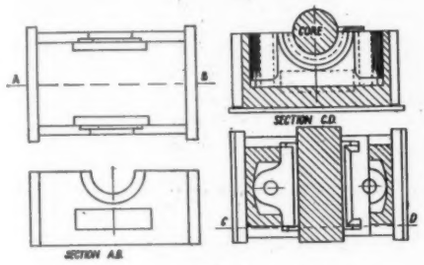

FIG. 1.

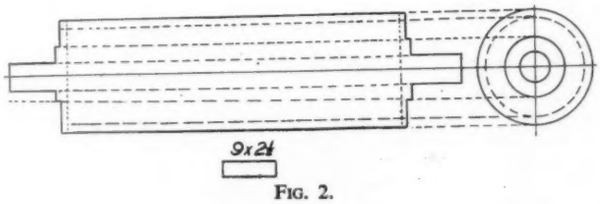

FIG. 2.

One of the best white metals is what is known as babbit No. 1, the alloy consisting of 90 per cent. tin, 4.5 per cent. copper and 5.5 per cent. antimony. This composition has no contraction or expansion and no allowance is necessary for either when preparing the patterns to be used for this purpose.

Making a Phosphor-Bronze Roller

Figs. 2 to 5 outline a method adopted for making a phosphor-bronze roller, cast in an alloy specified as being resistant to the action of sulphuric acid. The casting had to have an equal balance and, therefore, be of uniform thickness throughout the main walls. Substantial trunnions were incorporated at each end, and the path of escape for the gases from the core was through four 1½-in. holes at the end, located between the trunnion and the outer wall of the casting. To support a 14-in. dia. core and keep a perfect thickness equality presented a problem that is not an everyday experience in any foundry; and much careful thought was demanded before the best method of procedure could be satisfactorily decided. It was soon obvious that the usual lines practised would not succeed in this case. It was therefore decided to begin by replacing the trunnions with core prints and leave the trunnions to be added to the casting after the cylindrical part had been cast. The illustrations show how this was accomplished.

The size of the core necessitated the use of a reasonably stiff core bar, and a 3-in. bar was chosen. Three aluminium grids, details of which can be seen in Fig. 3, were wedged in position on the bar. All the wedges were driven in the same direction, so that quick release could be obtained by driving the bar in the opposite direction. Also, in order to stiffen the straw rope and to prevent sagging, when the core was half struck up, hooks were fixed from the two end grids to support the straw and loam and to make a more rigid core. This arrangement proved entirely satisfactory.

It will be obvious that with a mould of this description it was not possible to cast in a horizontal position, and, the job being cast in non-ferrous alloy, chaplets could not be used, so that the mould when prepared had to be placed on end and the core secured to the moulding box at the bottom end of the core barrel. At the top end, runners were placed on the joint, and space was arranged on the side for the gases to escape.

After casting and dressing the cylindrical portion of the casting, the next step was to insert the displaced trunnions. Naturally, this had to be done by welding, and the first attempt proved a failure. This effort was made by making trunnion castings and trying to weld at four points, but examination showed that cracks had developed at each point. This attempt is illustrated in Fig. 4.

Fig. 5 illustrates the successful method. The casting was placed on end in a pit, the inside being filled with sand and the space between the casting and the pit rammed up to floor level. A joint was struck off, and the trunnion pattern was placed in position in the centre to form the trunnion mould, and four riser patterns were placed as shown in Fig. 5 to receive the weld metal as it flowed through from the trunnion, which was used as the pouring centre. After this "welding"-mould had been rammed up, it was removed, the patterns withdrawn, the mould dressed, and a coat of blacking applied. The mould was then skin-dried and the casting heated so as to assist in the contraction and prevent cracking. After one end had been treated in this way, the casting was reversed and the same procedure followed for the other end. It should also be noted that, when doing work of this kind, it is necessary to run sufficient metal through the job to raise the temperature of the body casting so that there will be something like an equal contraction influence.

The method described and illustrated in Fig. 5 proved quite successful, and the casting has now been in service over 18 months without revealing the least sign of defect.

A theory generally accepted by engineers is that the weakest part of the weld is at or near the end of the weld. This is only partly correct so far as non-ferrous metal work is concerned, for it depends on the method adopted in the welding. If welded by electric or acetylene methods, it appears to have a greater tendency to occur; it also occurs in burning on, but only when the metal to be welded is under tension, and such a spot was yielded by the first attempt with the trunnion job illustrated in Fig. 4. When, however, the metal has freedom to come in, the break takes place sufficiently remote to contradict the theory.

A Practical Welding Test

Two bars were cast, as shown in Fig. 6, from the same pot. One bar was sawn in half and welded, the other left in the as-cast condition. Both bars were put under tensile test, and it will be noticed that the break occurred at least 4 in. away from the end of the weld; the metal also appeared to give a better elongation at the point where the metal was joined.

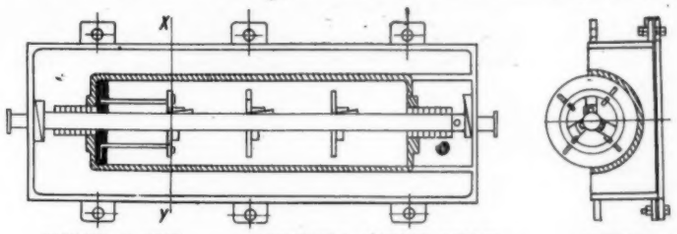

FIG. 3.

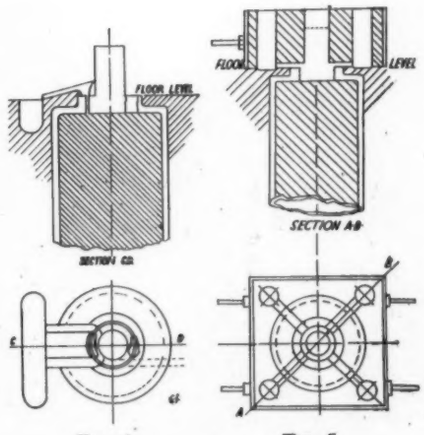

FIG. 4. FIG. 5.

After the foregoing experience there is real justification for concluding that the system illustrated has a considerable advantage over the other methods mentioned, so far as non-ferrous metals are concerned. The chief objections to the other methods are that they generate too high a temperature and have a tendency to burn the alloys, thus taking the natural strength out of the combination. With the method described, it is only necessary to raise the temperature of the alloy to a point adequate for casting and then apply it to the joint until

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* Extracted from a Paper presented to the Wales and Monmouth Branch of the Institute of British Foundrymen at a meeting held in Cardiff.

† Managing director, Williams Alexandra Foundry, Limited, Cardiff.

the body has reached the same temperature. Experience will soon indicate the correct procedure to obtain the desired result.

The type of metal to be used for welding should be the same as the castings to be welded, but if a tough metal is to be welded to a metal of a lower grade of toughness, tough metal should be used for the welding purposes. The addition of a little spelter (up to 2 per cent.), with the addition of a little phosphor copper with the successful use of the casting, if it does not exclude its use altogether.

Making a Pickling Cradle

Fig. 7 illustrates a pickling cradle for the tinplate and galvanising trades. Such assemblies are made in two sections and are welded together to make the complete units as shown. They are 14 ft. long, 2 ft. 9 in. deep, and 3 ft. 6 in. wide, and should contract 2¼ in., but the obstruction of the unequal parts is too great to permit the proper contraction to take place, with the result that the casting will crack and become a waster. Prior to adopting the welding method, they were made in sections and bolted together, but there was always an objection to this practice. Riveting was also used, but this had disadvantages. These methods each necessitated machined joints and drilling holes in different positions. The sides, ends and base were separate castings. The trunnions were also made separately, machined, and fitted to the other castings, the trunnions being made from rolled phosphor bronze. All this work meant expense as well as delay in giving delivery, but, worse still, the acid always attacked the bolts and rivets first, and it was necessary to be continually tightening or renewing them, which was far from what was desired.

The cradles shown are solid castings, and it can readily be seen how much more economical the solid casting will be in use when it is mentioned that the contract called for a three years' guarantee. Obviously a method was demanded that was attended by the least danger of breakdown.

TENSILE TEST
Acid Resisting Metal for Pickling Cradles (chill cast)
(NOT WELDED)
Load at failure 24·3 tons
15·8 tons per sq. in.
Supplied by Williams (Alexandra) Foundry Co., Cardiff.
Tested at University College, Cardiff.
TENSILE TEST
Welding - Acid Resisting Metal for Pickling Cradles (chill cast)
Load at failure 26 tons
14·0 tons per sq. in.
(broke away from weld)
Supplied by Williams (Alexandra) Foundry Co., Cardiff.
Tested at University College, Cardiff.
WELD

FIG. 6.—TESTING RESULTS ON CAST BARS.

just before pouring, will help in ensuring a sound weld. For example, if one has to weld phosphor bronze, add spelter, but when welding gunmetal add phosphor copper.

The possibilities of a perfect weld in brass-foundry practice will often prevent the loss of a difficult casting. This particularly applies to castings where contractions are such that the tension set up on account of the casting being unable to contract will either leave the metal in tension, or cause a crack which will interfere

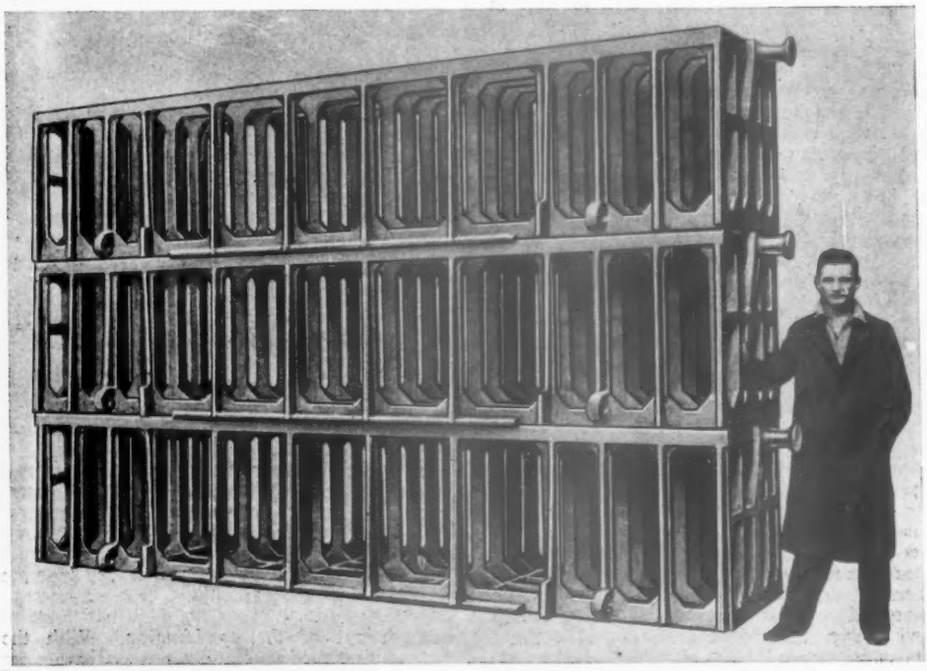

FIG. 7.—A COMPOSITE CAST AND WELDED PICKLING CRADLE.

Another cradle made was 11 ft. 6 in. long, and the same method was used as with the last one. Lugs were fixed to the side for tilting, while the cradle was suspended by the trunnions. These lugs were also riveted on the cradle at one time, but when it was found that welding could be accomplished so successfully, they also were welded on to the cradle after casting. The author's usual practice is to set up the parts in true alignment, leaving ¼-in. clearance between the parts to be welded, and after the top side has been completed the casting is turned over and the underside treated in the same way. Because of the extra wear and tear on the trunnions and lugs, it was advisable they should consist of another and tougher type of alloy, because they were called upon to stand the lifting strain of about four tons every half-hour, and when they had been bolted on they were constantly requiring attention because they kept coming loose with the action of the acid combined with the weight to be lifted. Here it was possible to weld the two types of alloy and, at the same time, eliminate the troublesome method of machining and bolting.

Another assembly of castings was 11 ft. long and weighed 1 ton 7 cwts. It was welded from three parts and two stiffening bars welded across. All holes in the base were tapered cored holes —not machined ones—and in order to get them true, after the cores were placed in the mould, a template was dropped over the top of the cores, after which they were secured in position by the top prints taking the cores as the top part was lowered into position. Two methods can be used for running this type of casting, giving a choice of two bushes cast in different alloys, the weight being about 100 lbs. The one can be of phosphor bronze, the other manganese, aluminium, or chromium bronze. The

reason for the different runners is that phosphor bronze is protected by a film of phosphide of copper which prevents the atmosphere from attacking the metal. The casting temperature of phosphor bronze should be such that it refuses to melt metal of its own composition. It is also an advantage to use runners that will give a spinning effect if that can be maintained until the mould is full. The other metals have no protection from the atmosphere and, therefore, call for a type of runner that will maintain a choking effect to prevent the entrance of oxide and allow the moulds to fill more slowly.

Chromium Bronze

Chromium bronze, which has been mentioned, is somewhat new to the author, but since taking it up, he has found it to be a very valuable line. It is specially suited for bearings and guides working under heated conditions, such as bearings working on hot neck rolls, wearing pads in rolling mills, and guides in rod mills, the life given being much superior to that associated with phosphor bronze alloys.

Another job of interest is an 88:10:2 cylinder casting which must withstand a pressure of one ton per sq. in. The casting is 5 ft. 6 in. long, 7½ in. dia., with a 5-in. dia. core, and weighs about 6 cwt. At the bottom, the hole to be cored is only 1¼ in. dia. and the use of a steel core 1¼ in. dia. driven into the end of the core bar gave satisfaction at that point, but a riser weighing 2 cwts. placed direct on the top of the casting when cast on end was thought necessary. As a leakage still will sometimes occur near the two bosses on the side of the top portion, the author is still looking for a cure for this.

DISCUSSION

MR. H. J. V. WILLIAMS asked if the lecturer would state any kind of rule for making feeding heads. He had found that by following a fixed process it was possible to get a wide variation of results. Was it possible to establish one to meet all cases?

MR. WM. WILLIAMS, in reply, said that all alloys had different peculiarities. In the case he had illustrated, 2½ cwts. of head pressure would not overcome the difficulty. He considered it was a severe test to put 1 ton per sq. in. on Admiralty gunmetal and was of the opinion that if contact could be made with the previous makers of orders received, much useful help could be obtained.

MR. W. S. KINSMAN asked if the leakage was at the bottom of the core.

MR. WILLIAMS said the leak was at the thickest part of the neck and one thing that made matters worse was that they had many uneven thicknesses at this part.

MR. THOMAS asked whether any phosphor copper was used as it might have helped to overcome the trouble.

MR. WILLIAMS replied that no additions of any kind were permitted.

MR. H. J. V. WILLIAMS asked whether a bush was used for the runner, or whether the metal was run direct into the casting.

MR. WM. WILLIAMS said the metal was run in around the core on top of the two lugs.

MR. REES asked whether it was possible to run the metal down the centre of the core.

MR. WM. WILLIAMS did not think that would be a solution to this particular problem.

MR. H. J. V. WILLIAMS asked what was the reason for having a small neck on the runner of a certain pump casting.

MR. WM. WILLIAMS said the object was to keep the alloy from oxidising as much as possible.

MR. J. F. GIST asked whether use was made of the method by which the metal was brought to a pasty condition and then allowed to cool down, and finally remelted before casting.

MR. WM. WILLIAMS replied that this system was followed to obtain soundness in very important aluminium castings.

Vote of Thanks

Both MR. KINSMAN and MR. H. J. V. WILLIAMS, who respectively proposed and seconded the vote of thanks to the lecturer, made appreciative references to the valuable character of the Paper, based as it was on the long and exceptional character of the author's practical experience.

The vote was accorded with acclamation, and MR. WILLIAMS suitably responded.

Some Jobbing Foundry Experiences—I

By "TRAMP"

The modern tendency towards specialisation in engineering and foundry work has resulted in the elimination of many of the smaller jobbing foundries. These little country shops often supplied their neighbourhood with the various castings required by the agricultural community, the urban authorities and any quarries or mines in the district. Nowadays, much of this work, such as manholes and covers, is standardised and produced in mechanised foundries at a figure often below that at which the country jobbing founder can compete. That this is to the common good cannot be denied, but the tragedy is the closing of many shops which have turned out much useful work in the past. Some specialised plants regularly utilise a jobbing foundry to make all their requirements out of the standard run of business. This is a good policy as it helps to keep the spirit of craftsmanship alive, and youths trained in such foundries are more adaptable and useful to the industry than those whose experience has been confined to one particular line of casting.

Unfortunately many young craftsmen and apprentices have not the advantage of obtaining

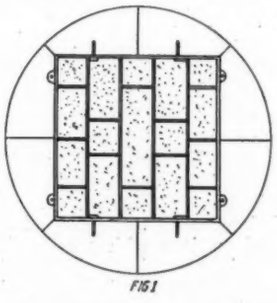

FIG 1

FIG 2

actual experience in jobbing work and the following notes have been written for their benefit. Although much that will be described may be foreign to their everyday work, some useful hints may be found that could be applied in the future if ever they change their place of employment. Many jobbing shops are greatly handicapped by the lack of adequate lifting appliances. Those usually available are, in many instances, single jib cranes which only span a portion of the foundry floor. Because of this moulding boxes must be on the light side and as far as practicable made for easy man-handling. Also much of the heavier work has to be either made in green sand or skin-dried because of the numerous difficulties in loading and unloading a drying stove. Hence much work is cast in jobbing shops in green sand which in other shops possessing better lifting facilities and modern drying stoves would be cast in dry sand.

As a far greater degree of skill is required to produce green-sand castings it is often found that many jobbing moulders are superior craftsmen to many of their fellows who work in better equipped establishments. The following is an instance of some of the difficulties encountered and the method employed to surmount them.

The first instance is that of a large spur wheel which measured approximately 8 ft. in dia. and was a fairly large job for the shop. The largest moulding box available was only 5 ft. square and as the price which could be obtained for the job did not warrant the manufacture of a new box, which would probably have been used only for that particular order, other ways and means had to be adopted.

A segmental pattern was employed to mould the bottom in the foundry floor, while a pattern of an arm was used to form the number of arms required, which were of T-section. As it was not possible to cast the job open-sand, the following expedient was adopted to close the mould. First the 5-ft. square box was rammed up and centred over the mould; then around this were placed prepared loam plates with a coating of loam approximately 1 in. thick. These were all securely weighted down to resist "lift" and the job was successfully cast. Fig. 1 shows a plan of the box and the eight loam plates in position, while Fig. 2 shows a view of the underside of one of the plates with prods cast on to hold the loam. Such is one example of the difficulties of a jobbing founder and the means of overcoming them with the minimum of expense.

Australian Ironfounders and War Conditions

The annual report of the Ironfounders' Section of the Victorian Chamber of Manufacturers was submitted to members at the annual meeting recently. During the year seven general meetings of the Section were held, in each case preceded by an informal dinner. Addresses have been given by Mr. W. T. Main, who spoke on "Balanced Blast Cupolas"; Mr. E. Davies, on "Foundry Coke"; Mr. A. Tennant, on "Foundry Practices in Australia and Abroad," and Mr. D. L. Lemon, on "Foundry Costing," while Mr. E. J. McDonald showed a selection of pictures taken during trips into the interior of Australia and oversea countries.

A dinner and social evening in December last, to which were invited the Presidents, secretaries and organisers of the Federal Moulders' Union and the Ironfounders' Employees' Union, was an innovation generally appreciated.

Industrial troubles were few during the year under review. The Committee conferred with the Federal Moulders' (Metals) Union regarding a basis for the work of overtime and with the Ironfounders' Employees' Union regarding the payment of rates by the Steel Company of Australia (Pty.), Limited. Both cases were satisfactorily settled.

The question of supplies and prices of mild steel and cast-iron scrap was the cause of a good deal of concern, said the Report. The matter had been taken up with the Customs Department, and a survey made by an officer of that Department. Following the report made by this officer, the Government declined to place an embargo on the export of scrap. The Committee of the Section is now seeking a satisfactory method of controlling prices of scrap. It has been suggested that this might be done by purchasing supplies through a central agency of selected dealers, and at the present time this suggestion is being investigated. Such a move will, of course, require the fullest support and co-operation of all members of the Section.

In conclusion, the report stresses the importance of a fuller representation of members at meetings of the Section, and states that in the present difficult circumstances there is an urgent necessity for the fullest co-operation of all members in matters relating to this important branch of the engineering industry.

The following office bearers have been elected for the ensuing year:—Chairman, Mr. F. Ayre; deputy chairman, Mr. G. Graham; committee, Mr. W. L. Allen, Mr. S. C. Burch, Mr. R. L. Cox, Mr. P. N. Davies, Mr. D. Duncan, Mr. F. Groves, Mr. T. W. Izzard, Mr. W. T. Main, Mr. G. Muir, Mr. V. R. McKay, Mr. F. C. Paynter, Mr. W. H. Steele, and Mr. A. Tennant.

Production of Pressure-Resisting and High-Duty Castings

Discussing MR. J. L. FRANCIS'S Paper bearing the above title, which had ben prepared for presentation at the annual meeting of the Institute of British Foundrymen, and which appeared in our issues of June 20 and 27 and July 4 last, MR. E. LONGDEN wrote:—

The Paper prepared by Mr. J. L. Francis is of outstanding merit, both by its common sense and its completeness in summary of complementary data. I would recommend foundrymen to keep this work of Mr. Francis as a reference. The Institute of British Foundrymen should not miss recognition of the very helpful, practical contribution to the manufacture of castings.

May I, however, just refer to certain sections of the Paper which need to be noted?

On page 9 of the advance copy of the Paper it is stated—"Pressure-tightness and good wearing qualities are main characteristics striven for in the castings described. For these properties nickel alone, or in combination with copper, *suffices* to render thick sections dense and *sound* and maintain thin sections grey and machinable. Alloying is accordingly restricted to the use of these two metals in the majority of cases."

I suggest that if the word "suffices" (enough) be replaced by the word "tends" (to contribute) one can agree with the beneficial effects of nickel and copper when due consideration is given to the balancing of the elements normally present in cast iron. The selective graphitising effect of nickel and copper, so that the pearlite carbide tends to remain as carbide but in a more refined condition, and the graphitising influence of the added alloys on the free carbide will produce stronger and more wear-resisting metal than in metal without the added elements and its adjustment in other elements. Apart, however, from the slight effect of small amounts of nickel on the freezing point of cast iron, section differences and the contingent defects are not at all completely appeased by employing nickel, copper or other element. If alloying elements eliminate defects, why use denseners which Mr. Francis uses so effectively?

Effect of Densening

When referring to the production of heavy coupling castings illustrated in Fig. 9, it is stated that "The amount of liquid shrinkage which takes place can be seen from the sunken condition of the extended solid boss." I would suggest that the sunken condition of the head does not expose real fluid shrinkage, but rather does it indicate a condition resulting from the pouring of cast iron, of grey iron composition, into normal sand moulds. If Mr. Francis will pour the heavy coupling in an iron mould, or in a mould almost completely faced with denseners, he will be repaid with the evidence obtained—the castings will be commercially sound. Furthermore, it will not be necessary to provide a head to take care of liquid shrinkage; it will only be necessary to add sufficient extra metal (¼ in.) to take care of sullage. To obtain this result the metal should be of such a composition that it yields a grey iron throughout its sections and the runner gates should be surrounded by sand and well distributed, and a small gas outlet riser gate be located on the highest point of the mould. I do not, however, suggest it is often commercially practicable to produce castings in such a manner. It depends on the simplicity of its design and its mass.

As I have frequently stated, due to the expansive effect of precipitated graphite carbon at the point of solidification, it will be found that, in normal cast irons of grey iron composition, it is possible to produce sound castings without resort to the employment of feeder heads.

The Léonard Effect

I would suggest that the shrinkage and porosity effect of wedge-shaped portions of sand, which create gassy and hot spots, referred to as the "Léonard Effect," should be re-named the "Fletcher Effect" or the "B.C.I.R.A. Effect," or named after other men I have in mind. The British Cast Iron Research Association put the diagnosis of this phenomenon on its best-known basis long before we learned of Léonard. Fletcher afterwards referred to this aspect of porosity both inside the authority of the British Cast Iron Research Association and in his lectures to technical bodies, particularly to the Institute of British Foundrymen. I for one shall in future refer to the "Fletcher Effect." It is a trait in the British character to take too small notice of our own nationals and too much notice of foreigners in technical as in other matters.

AUTHOR'S REPLY

MR. J. L. FRANCIS wrote that, before dealing with the points raised by Mr. E. Longden, he wished to record appreciation of his kind remarks and approval of the Paper as a whole.

Alloyed Cast Iron.—The wording of the second paragraph under this heading could have been better chosen. It was intended to differentiate between the use of alloys for imparting special properties other than those mentioned, *e.g.*, high hardness, corrosion and heat resistance, and to emphasise that copper and nickel alone are sufficient to induce the necessary pressure tightness and resistance to wear. Neither nickel and copper nor any other elements singly or in combination in cast iron can give complete immunity or guarantee the entire elimination of defects, and there was no intention to convey the idea of any such foundry millennium.

Although alloy additions can effect modification of structure, they do not achieve this by any adjustment of cooling speed. Sections of varying thickness solidify under the same differential characteristics, despite the presence of alloys. Denseners, therefore, though perhaps not so necessary, can still be useful in rendering cooling more uniform and reducing the tendency towards formation of shrinkage cavities at places where feeding cannot be applied.

Coupling Castings.—Mr. Longden's method for producing commercially sound castings, such as are illustrated in Fig. 9, is interesting. The system described in the Paper also produces commercially sound castings with greater simplicity and latitude in operation. It has the advantage, moreover, of always being practicable without much limitation due to design and mass of the coupling.

Fletcher Effect.—I am perfectly willing to use this term in place of "Léonard Effect" in describing the porosity emanating from overheated portions of sand. Mr. Longden may be correct in crediting priority of diagnosis of this type of defect to British workers. I merely used the designation as being well known in the literature on the subject and because it has previously been accorded unquestioning acceptance as conveying conception of a definite condition. I would much rather be accused of ignorance than lack of patriotism or willingness to accord due recognition to British workers.

Discussion Invited

Written discussion of two of the seven Papers which were prepared originally for presentation to the Institute of British Foundrymen in June is printed on this page. Members of the Institute are reminded that written discussion of the Papers is earnestly desired and that contributions should be sent to Mr. John Bolton, St. John Street Chambers, Deansgate, Manchester, 3.

Test-Pieces for Steel Castings

The Paper on "Design of Test-Pieces for Carbon Steel Castings,"* prepared by MR. C. H. KAIN and MR. E. W. DOWSON for presentation to the Institute of British Foundrymen has been the subject of the following written discussion:

MR. F. W. ROWE, M.SC., wrote:—This design of test-block is a matter to which the writer has devoted a certain amount of time, but without the successful results which appear to have attended the authors' efforts. It is thought that answers to the following queries would be of general interest:—

(1) Is the clover-leaf type of test-block equally satisfactory with a 9-in. length of test-bar as with a 6-in. length?

(2) Is the comparative gross weight with head available as against the ordinary type of tongue block usually used, providing the same length of test-bar?

(3) At first sight it looks as though the clover-leaf test-block might be more expensive to cut up than the ordinary one. How is the block cut? Are the head and runner burnt off and then the three test-pieces milled out, or how? On the usual tongue block the writer cuts his test-pieces from the block with a hacksaw.

(4) In the majority of cases even now only two test-pieces are needed, either tensile and bend or tensile and impact, but a tongue block about the same proportions as are shown in the Paper is called for, because the "C" portion is, as the Paper proved, usually rather poor.

(5) Could another Paper be written on the best design of test-block where only two test-bars are needed?

AUTHORS' REPLY

The AUTHORS answered Mr. Rowe's queries as follows:—

(1) The clover-leaf test-block has been found to be perfectly satisfactory for test-bars as long as 15 in.

(2) The clover-leaf type of bar is a few pounds lighter than the equivalent tongue type of block made for three bars.

(3) The question of cutting off the bars is an awkward one, and it is usual to slit down the three tongues with an oxygen cutter before heat-treating. The bar can then easily be cut off with a hacksaw.

(4) Even where only two test-pieces are required, it is the practice always to provide three in case a spare is required or in case of dispute.

(5) There can be no doubt that the time will come when the impact test will be much more generally used than it is to-day, and it is really advisable to be prepared to produce three good test-bars, when required. No great difficulty is thought to arise in the production of three test-bars of reasonably uniform properties.

Molybdenum in Enamels

The results of a large amount of work undertaken by the Climax Molybdenum Company on the use of molybdenum compounds in vitreous enamelling were presented to the American Ceramic Society recently. The difficulties encountered in the use of the tri-oxide, MoO_3, have been surmounted by the substitution of the di-oxide MoO_2. This is added as a mixture with antimony oxide in the proportion of about two Sb_2O_3 to one MoO_2, and three to four parts by weight of the mixture are used per 100 parts frit. The antimony-molybdenum combinations give adherence comparable with typical cobalt ground coats, over which the following advantages are claimed:—(1) Lower cost; (2) greater covering power; (3) very slight reboil; (4) the possibility of making low-temperature ground coats; (5) the possibility of finer adjustment of the ground coat at the mill.

* See FOUNDRY TRADE JOURNAL, June 13, 1940, pp. 435-6.

Steel Melting in Electric Furnaces

CHEMISTRY OF THE PROCESS

A conference, sponsored by the Steel Founders Society and the Electric Metal Makers Guild, was recently held at the Battelle Memorial Institute, when various Papers relating to several aspects of electric steel melting were presented. These could roughly be divided into two classes: (1) Actual operations and (2) fundamental chemistry of the process. In the second class was a Paper on "Fundamental Physical Chemistry of Steelmaking" by C. H. Herty which, after presentation, was supplemented by C. E. Sims, research metallurgist at the Battelle Memorial Institute. These two contributions are reviewed by A. J. SCHEID in a recent issue of "Metal Progress" from which the following extracts are taken.

After introducing his Paper DR. HERTY stated that much had been written about the dynamics and thermal effects of reactions assumed to be taking place at 1,490 to 1,705 deg. C., but that these equilibria were only one of four general actions that must be recognised: (1) Solubility; (2) reactions and equilibrium; (3) diffusion; and (4) flotation. These are individually discussed below.

Solubility

One of the first things that happens in steel melting is that FeO gets into the metal which is later useful in removing certain undesirable elements. The rate of solubility depends on the temperature; increasing temperatures accelerate the rate and greater quantities can be dissolved at increased temperatures. Thus, at the melting point of steel only about 1 per cent. FeO can be dissolved in iron but with higher temperature this is greatly increased. Iron oxide is only one of the constituents that may find itself either in the molten metal or the slag. One problem in physical chemistry is to determine how this partition changes with circumstances, and it has been found that for each temperature there is a certain "distribution ratio." For example: The amount of FeO dissolved in the steel is proportional to the amount present in the slag. This proportion remains constant at a given temperature—that is to say, given enough time to attain equilibrium, there is no further change in the relative amounts. Iron oxide leaving the metal bath for the slag is matched by an equal amount leaving the slag somewhere else and entering the metal. If the temperature should then rise, the equilibrium would be upset, and the oxide would go from metal to slag (or *vice versa*) until a new distribution ratio is established at a new constant temperature. This same principle applies to other elements that will dissolve in both steel and slag.

Reactions and Equilibrium

To illustrate the mechanism of chemical reactions Dr. Herty took the case of a steel bath containing 1 per cent. Mn to which FeO was added (by oreing or otherwise) so as to upset the equilibrium within the steel itself. The reaction to be expected would be: Mn + FeO → MnO + Fe + heat.

When equilibrium has been reached, the reaction may be thought of as going in both directions simultaneously:

$$Mn + FeO \rightleftharpoons MnO + Fe.$$

If MnO were added in place of FeO, the reaction would go in the reverse direction:

$$Mn + FeO \leftarrow MnO + Fe - heat.$$

Since the oxidation of manganese gives off more heat (54,200 units) than the dissociation of an equivalent amount of iron oxide absorbs (33,950 units), the reaction generates heat when it moves from left to right. Such an exothermic reaction may reverse if the temperature rises sufficiently (or, more properly, comes to equilibrium with more FeO present), which corresponds to the known fact that the deoxidising power of manganese diminishes with increasing temperature.

For silicon the typical reaction is:

$$Si + 2FeO \rightleftharpoons SiO_2 + 2Fe + heat.$$

The heat balance from oxidation, reduction and solution results in a larger amount evolved than in the manganese reaction. If the metal increases in temperature, this reaction "reverses," as indicated above. Thus, the amount of silicon reduced from silica in slag particles or from the lining in an acid furnace increases with increasing temperature.

If the reaction absorbs heat, it tends to increase in activity with increased temperature. Phosphorus control is based on this fact. It should be noted that there usually is an increase in phosphorus in the metal with increased metal temperature, other things being equal. The reaction between carbon and FeO is:

$$C + FeO \rightarrow Fe + CO\uparrow$$

In this reaction the CO is only slightly soluble in the metal, the greater quantity going off as a gas. This reaction continues in the one direction because one of the products is rapidly removed from the steel. The slight solubility of CO, it is stated, is the only reason it is not possible to make absolutely carbon-free iron easily.

From this brief discussion it is evident that there are two typical classes of reactions involving characteristic types of products:

(1) Reaction products that may reverse, interchange, and reach apparent equilibrium.

(2) Reaction products, one of which leaves the furnace, and therefore the reaction trends definitely in one direction only. Of course, removal of a slag will prevent reversal of reactions between metal bath and slag cover.

The speed of reaction is proportional to the concentration existing in the reacting media. In the case of manganese and silicon, the rate of reversal depends on the analysis of both metal and slag. The distribution ratio for manganese may be denoted by K_{Mn}, and this is calculated from the equation

$$K_{Mn} = \frac{(MnO)\cdot[Fe]}{(FeO)\cdot[Mn]}$$

where the parentheses indicate that the concentrations to be used are those in the slag, and the brackets the concentrations in the metal.

Flotation

If dirt is thrown into water, a settling rate, varying with particle size, can be observed. Large particles separate rapidly and the more minute particles settle at a very slow rate. If hot water were used, the settling of even fine particles would take place more rapidly. Thus, the speed of settling depends (*a*) on the size of the particles and (*b*) on the viscosity of the liquid.

In steel the settling is up rather than down, due to the relative specific gravities of the materials involved. Increased temperature will cause particles to float out faster; likewise increased size of particles will cause them to rise more rapidly. Further, increased temperature makes slag particles more fluid, increasing their tendency to coalesce and rise at a more rapid rate.

Effect of Other Reactive Substances

Mr. C. E. Sims then pointed out that conditions were greatly complicated by the number of reactive substances present in an electric furnace charge. For instance, the "basic" oxides present in the steelmaking process are CaO, MgO, FeO, MnO, Al_2O_3, and the "acid" oxides are SiO_2, Fe_2O_3, Mn_2O_3, Al_2O_3 and P_2O_5.

Pure SiO_2 and CaO have very high melting points, and to utilise them as slag-making materials, they should be sufficiently fluid to act as a suitable carrying agent. Fluxing can be obtained in two ways:—(1) By chemical combination—a base plus an acid results in a low-melting point slag. Thus:

$$CaO + SiO_2 \rightarrow CaO\cdot SiO_2.$$

Melting points of these three substances are 2,571, 1,713 and 1,538 deg. C. respectively. (2) By causing one substance to become soluble in another. In acid practice, FeO may possibly be dissolved in SiO_2 in varying proportions.

An oxidising slag has been variously defined; it may be thought of as one having a tendency to give up oxygen to the steel. Oxygen in slag may be closely held in a stable compound, or rather loosely held in a compound that can readily migrate—so loosely held that it may act as free oxygen in solution.

For example, if the FeO is combined with SiO_2 in an acid slag, there can be but little reaction. However, by adding CaO the following reaction takes place:

$$FeO\cdot SiO_2 + CaO \rightarrow CaO\cdot SiO_2 + FeO,$$

whereupon the FeO is available for solution or reaction in the metal. In basic practice, if the FeO and the slag are combined as $CaO\cdot Fe_2O_3$, the slag is very fluid and neutral, but if SiO_2 is added, the oxidising power will be increased because the chemical combination is broken up and the FeO is made available. Conversely in acid-slag practice, a slag low in FeO and high in SiO_2 will take FeO from the steel.

In basic-slag practice, a white slag deficient in FeO will rapidly dissolve FeO from the metal, in amount depending on its ability to enter into chemical combination.

Acid-Slag Practice

In acid-slag practice the phosphorus and sulphur cannot be removed from the steel. The oreing period has three functions:—(1) To oxidise carbon; (2) to oxidise manganese (not as readily oxidised as silicon); and (3) to oxidise silicon (readily oxidised). In these reactions the first to reach prominence is

$$C + FeO \rightarrow Fe + CO\uparrow$$

When the FeO is depleted, the reactions slow down because of the approach to equilibrium. This reaction probably never quite reaches equilibrium due to resistance to bubble formation. The initial small bubble has very high surface tension and a pressure has to be built up to get a bubble started. Once started, the bubble enlarges rapidly.

Some reactions involved are exothermic:

$$Si + FeO \rightarrow Fe + SiO_2 + heat.$$

As pointed out by Dr. Herty, the entire course of the reaction may be changed in superheated baths. In other words, the silicon will react with iron to form iron oxide, and some silicon will be reduced from the slag. At temperatures above 1,705 deg. C. carbon becomes a better deoxidiser than silicon.

These principles explain why, in a small electric furnace, when a high degree of superheat is necessary—as for pouring intricate or thin-walled castings—it is virtually impossible to prevent the reduction of some silicon. This silicon may be reduced under furnace conditions that are oxidising, as far as carbon is concerned.

Basic-Slag Practice

In basic-slag practice, approximately the same reactions take place between carbon, manganese, silicon and oxygen as in acid practice. Basic practice is also designed to take advantage of the high "affinity" of phosphorus for oxygen at relatively low temperatures. Mr. Sims, to illustrate this point, did not use the simple re-

action between elemental phosphorus and iron oxide (FeO), but denoted it thus:

$$2Fe_3P + 8FeO \rightarrow (FeO)_3P_2O_5 + 11Fe.$$

This reaction will reach equilibrium quickly with the oxidation of but little phosphorus in the absence of free lime. In the presence of lime, however, a stable phosphate is formed by this reaction

$$(FeO)_3P_2O_5 + 3CaO \rightarrow (CaO)_3P_2O_5 + 3FeO$$

which acts to prevent reversal of the other reaction. This dephosphorising reaction requires a large amount of FeO and free lime in the slag to remove much phosphorus. Dephosphorising slags are usually removed from the furnace to prevent reversion of phosphorus to the metal.

Sulphur is removed from the bath by the following reaction

$$CaO + FeS \rightarrow CaS + FeO$$

and its transfer from bath to slag depends on the ratio of CaO to FeO in the slag. Since there is little CaO and much FeO in an acid slag, it absorbs little sulphur. The conditions are reversed in a basic slag. The calcium sulphide formed is very insoluble in the steel but highly soluble in the basic slag, and the reaction reaches equilibrium very quickly. Carbon added to such a slag to form a carbide slag prevents a reversal of the desulphurising reaction by disposing of the FeO. Two reactions are effective:

$$CaO + FeS + C \rightarrow CaS + Fe + CO \uparrow$$

$$CaO + 3C \rightarrow CaC_2 + CO \uparrow$$

As remarked above, these equations travel as shown because one of the products is carried away permanently. Desulphurisation of the metal can therefore be almost complete under a carbide slag.

If the silicon is below 0.25 per cent., there may be some reaction between FeO and carbon in the mould, forming CO gas. However, if ample silicon has been added and the finishing temperature of the metal is low enough, solid (non-gassy) steel should result. The residual FeO content may be reduced further by means of aluminium.

However, it may be found that the steel still effervesces. This must be due to nitrogen or hydrogen or both. The source of the hydrogen may be from rust (a hydrated iron oxide), high humidity (moisture in the combustion air), or moist slag-forming materials.

The solubility of such gases as nitrogen and hydrogen in liquid steel increases with the temperature, and with the square root of the partial pressure of that gas in the atmosphere above the metal. To illustrate: If the partial pressure increased to four times, the gas absorption would double. Hydrogen is eliminated during a boil from FeO, by the reaction

$$H_2 + FeO \rightarrow Fe + H_2O \uparrow$$

Nitrogen can also be swept out of the metal during a good boil. However, both hydrogen and nitrogen tend to remain in cooling metal even to supersaturation, and it is a problem to get them to form bubbles and eliminate themselves before entering the mould and causing porosity.

Mr. Sims further said that if a bath has a certain amount of hydrogen and nitrogen in solution and CO can be made to bubble up through the bath, the CO bubble itself will come to equilibrium with the bath and carry out its share of both hydrogen and nitrogen. If enough bubbles are formed, a fair amount of the two gases is removed in this way. Hydrogen can also be removed from metal in the oxidising stage. However, if hydrogen is picked up while the metal is under a deoxidising slag, it will not be removed. Slag-forming materials, such as lime containing moisture, may be a source of hydrogen in the deoxidising stage when making electric steel. The metal has its lowest hydrogen content immediately after the boil; from this, the value of a vigorous boil is evident when sound steel is to be cast.

Structure of Liquid Metals

In a review by DR. A. LATIN of "The Structure of Liquid Metals," printed in the June issue of the Journal of the Institute of Metals, these interesting conclusions are drawn:—

The forces responsible for the structure of the solid metal or alloy persist to some extent in the liquid. From one point of view the liquid structure can be regarded as a highly distorted form of that of the solid. Perhaps this can be most clearly pictured from what has been called the "hole" conception.

Imagine some of the atoms removed from the lattice of the solid in a similar way as is done for the so-called "subtraction" structures, for example γ-brass. Now imagine the rest of the atoms re-arranged so as to fill up the spaces left as regularly as possible. If, in addition, the atoms are given large vibratory and translatory motions about their mean positions an irregular "structure" results which corresponds to that of the liquid.

Another very useful conception has arisen from comparison of the solid $\rightleftharpoons$ liquid transition with order $\rightleftharpoons$ disorder changes in solid alloys. This has been used, for instance, by Lennard-Jones and Devonshire in their highly-successful theory of melting. They have applied the theory to a face-centred cubic lattice, taking argon as an example. Wannier, too, has applied the idea of melting as an order-disorder transition to a diamond-type lattice. Frank also has dealt with this conception in a general manner, and has shown that it gives an insight into the phenomena of supercooling and nucleus formation.

A Fundamental Assumption

The fundamental assumption in such theories is that melting can be conceived as a continuous transition from the ordered state of the crystal to the disordered state of the liquid. The similarity between solid and liquid is further stressed by the fact that, as the phenomenon of diffusion in the solid state shows, translatory atomic movements can also take place in the solid. On the other hand, it seems to the author dangerous to carry this conception of similarity too far; it is best to avoid, for example, the application of a term involving the notion "crystalline" to the liquid.

In addition to this it seems possible to arrive at further conclusions of a useful nature:—

(1) The solid $\rightleftharpoons$ liquid transition in the face-centred cubic, hexagonal close-packed, and body-centred cubic metals is "homeomorphous," or practically so. That is to say, the solid melts to form a liquid of very closely allied structural characteristics. This is also indicated by the relatively small change in density and specific heat on melting, and the much smaller tendency for supercooling shown by these metals than by metals like bismuth, gallium, etc. The melting process is probably of a "sharp," *i.e.*, essentially discontinuous, nature. The theoretical work of Bernal (which has been criticised, however, by Frank) on a general distribution function for monatomic liquids supports this view, as well as his arguments that it is not possible to obtain a continuous series of distribution functions between that for the solid and that for the liquid. Furthermore, there seems to be no definite reason for assuming group formation of either a "microcrystalline" or cybotactic type in such liquids.

(2) For molten metals of which the solid structures deviate more or less largely from close-packing, the solid $\rightleftharpoons$ liquid transition is "morphotropic," *i.e.*, there are differences in structural characteristics between solid and liquid. Bismuth and gallium are outstanding examples, and metals like mercury and tin may possibly be regarded as occupying intermediate positions.

In liquid metals of this type, there may be said to be, to simplify matters to the utmost, two opposing tendencies: (*a*) a tendency for close-packing following a release of the atoms from the solid "bondage," and (*b*) a tendency for configurations to occur related to the crystal structure of the solid, owing to persistence in the liquid of forces acting on the atoms in the solid. Bismuth and gallium contract on fusion, but this contraction, according to the calculations of Sauerwald and Teske, is less than would be expected if the closest-packing were to result. There seems some reason to suppose that the transition is not of so "sharp" a nature as with the close-packed metals. There are several experiments which indicate this for bismuth. The assumption of a definite mesophase between solid and liquid does not, however, seem to be entirely justified at present. On the other hand, the hypothesis of cybotaxis gives, in the opinion of the present author, a good explanation of the phenomena.

It seems very likely that the two opposing tendencies described above give rise to groups of a transitory nature, *i.e.*, cybotaxis, which will be most marked just above the melting point. At the same time the tendency for close-packing will increase as the temperature is raised and probably reach an optimum value. Beyond this stage, the normal expansion with temperature increase is probably accompanied by an increased irregularity of the atomic configuration. These conclusions are also in line with the relatively high degree of supercooling that tends to occur, as well as with the changes in diamagnetism and electrical resistance that occur on melting. It is of interest to note that order-disorder changes in solid alloys are frequently accompanied by changes in the crystal structure. It might well be expected, therefore, that in some cases analogous changes in structural characteristics occur on melting.

Interpretation of X-ray Results

(3) Cybotaxis of a sort seems also not unlikely in molten intermetallic compounds. The X-ray results for these can be interpreted in two ways: (*a*) there is some tendency for molecules of the intermetallic compound to persist in the liquid; and (*b*) there is a tendency for atomic configurations in the liquid to resemble those in the solid. Since the forces responsible for compound formation and for crystallisation are undoubtedly related, these two statements are probably equivalent. That a form of cybotaxis is likely arises from the reasonable view that the atoms in the liquid are not permanently associated, but that the compound is, so to speak, perpetually forming and dissociating.

(4) The X-ray results for the eutectics can also possibly be best explained by the assumption of a form of cybotaxis. The general conclusion, obtained from much evidence besides that from X-ray work, that the forces acting in the solid state tend to persist to some extent in the liquid, makes the assumption of a tendency for separation of the components of a eutectic alloy in the liquid near the freezing point not unreasonable. It is very unlikely, however, that the regions consisting of one or the other of the more or less pure metals are of a permanent nature, but more likely that the atoms of the different metals are continually tending to intermingle and separate. Since they are in continual agitation it will be seen that this is feasible.

It is possible that these views may have to be modified in the light of further knowledge. Nevertheless, it is hoped that they will be useful as representing a wide attack on a subject of importance, as well as one step of a fundamental nature in the solution of the multifarious problems involving the solidification of metals in practice.

Pendulum Indentation Hardness Testing Machine

ITS USE AT HIGH TEMPERATURES

A new design of pendulum indentation hardness testing machine described by H. CORNELIUS and W. TROSSEN in "Stahl und Eisen," enables the hardness of metals to be measured at elevated temperatures. Arrangements are provided allowing the specimen under test to remain in the heater while the hardness is being measured; this permits a series of measurements to be made in quick succession and at various temperatures. At the same time, it avoids the disturbing drop in temperature

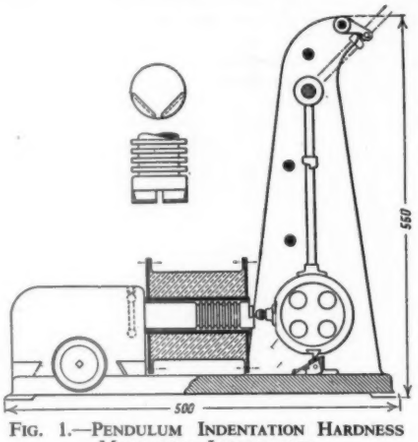

FIG. 1.—PENDULUM INDENTATION HARDNESS MEASURING INSTRUMENT.

obtained on removing the samples between individual measurements. The general design of the apparatus may be gathered from Fig. 1, which shows the sample clamp and the heater incorporated in one unit. Indentations are produced by means of a ball of a hard-metal alloy, 5 mm. in dia., which allows measurements on materials retaining a high coefficient of hardness at high temperatures, such as stellite. The pendulum hardness of metals with a Brinell value below 100 units is, however, measured with a ball of 10 mm. dia. A double swing by the pendulum is avoided by a stop which arrests the pendulum after making the first indentation. The holder securing the sample under test is made of a heat-resisting alloy, completely scale-resisting up to 1,100 deg.; it rests against a heavy water-cooled block. The rear surface of a sample is placed against this block, while the front machined end rests on the holder proper. The furnace is pushed over the holder in a horizontal direction, being mounted on rollers, and the assembly of block with sample holder and furnace can be displaced in the plane perpendicular to Fig. 1 by a hand-operated screwgear, the displacement being indicated on a scale. The temperature of the sample is measured by means of a thermo-couple consisting of a solid double-bore cylinder, the bare junction being placed in contact with a machined spot on the sample.

When hardness measurements at elevated temperatures are made, the furnace is drawn back just sufficient for the ball to strike against the sample, but without the pendulum coming in contact with the furnace body. During the time indentation is being made, the sample thus remains in the forepart of the furnace, the latter being returned to its initial position wholly to enclose the sample immediately after the pendulum has made impact. The whole operation of indentation takes only a few seconds. To obtain a second indentation in the same sample, the block assembly with the furnace, etc., is displaced slightly sideways across the pendulum.

The pendulum hardness can be expressed in the usual way by the energy of impact in mmkg. divided by the volume of the indentation in cub. mm., but this has the disadvantage that the unit of measurement is less well-known than the more common Brinell and Vickers hardness values. Calibration curves were, therefore, plotted which enable the experimental values given by this apparatus to be converted to Brinell and Vickers values. The curve applies to room temperature and was plotted from measurements on copper, brass, alloys in the Al-Cu-Mg series, Al-Mg, mild steel, Fe-Cu alloy with 1.5 per cent. Cu, structural steels St 37.11, St C 60.61, and VCMo 125 in the annealed states, Ni-Cr-Wo steel annealed to different hardness values, austenitic Ni-Cr steel and welded-on plates of stellite. The results obtained with cold-rolled samples do not conform with

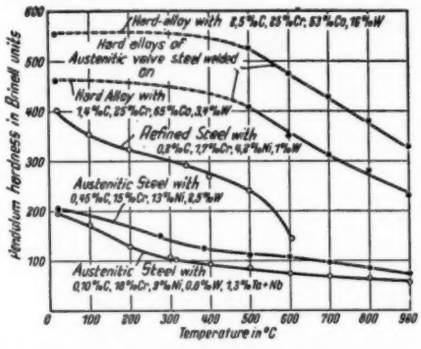
Pendulum hardness in Brinell units
Temperature in °C
Hard-alloy with 2,5%C, 25%Cr, 53%Co, 16%W
Hard alloys of Austenitic valve steel welded on
Hard Alloy with 1,6%C, 25%Cr, 65%Co, 3,9%W
Refined Steel with 0,8%C, 7,7%Cr, 0,2%Ni, 7%W
Austenitic Steel with 0,45%C, 15%Cr, 13%Ni, 2,5%W
Austenitic Steel with 0,10%C, 18%Cr, 8%Ni, 0,8%W, 1,3%Ta+Nb

FIG. 2.—PENDULUM INDENTATION HARDNESS OF DIFFERENT MATERIALS, PLOTTED AGAINST TEMPERATURE.

the calibration curve plotted in respect of non-cold-rolled samples. The temperature function of the pendulum hardness for different materials is reproduced in Fig. 2. It may be recalled that, already while the samples are being raised to the temperatures of measurement, copper begins to be precipitated and the hardness increases as a result. The shape of the hardness isotherms is similar to that obtained after annealing and measuring the Brinell hardness at room temperature.

Catalogues Received

Pumps. Mirrlees, Bickerton & Day, Limited, Hazel Grove, near Stockport, have just issued a new catalogue (No. 19740), which gives illustrated particulars of the Mirrlees-Imo rotary screw pumps. These are special-duty pumps which eliminate turbulence, noise, vibration and valves. Amongst interesting foundry applications are the tilting of electric furnaces, die-casting plant, and tensile testing machines. With the more general use of hydraulically-operated machine tools, this type of pump finds increasing application. The catalogue is particularly well printed and illustrated. It runs to 40 pages, and carries a handsome embossed cover.

Electric Heat-Treatment Furnaces. Birmingham Electric Furnaces, Limited, of Birlec Works, Tyburn Road, Erdington, Birmingham, 24, have just issued a publication (No. 24) which describes a range of electric heat-treatment furnaces. The range is indeed wide, the smallest having a hearth area of 16 in. by 8 in., and the largest 60 in. by 36 in. The maximum operating temperature yielded is of the order of 1,000 deg. C. The pamphlet sets out all the various features of the plant, such as heated door, and automatic and safety devices, in the form of a brief specification. A number of interesting illustrations are included. This pamphlet is available to readers on writing to the Birlec Works.

Copper Price Prospects

BY "ONLOOKER."

As the world's largest copper producer it was obvious that America would suffer seriously from a state of war in Europe, but it is safe to say that no one foresaw such a speedy and complete cessation of French demand. To the U.S. producers this is a serious blow, for France must have been taking on a conservative estimate 200,000 tons per annum, much of it probably from Chilean properties owned by American companies. Now, that copper is going begging, unless the Ministry of Supply takes it over, and such a course seems a little doubtful in view of the very large supplies reaching these shores from Empire sources. Owing to the 4 cents import duty which is payable on all foreign copper entering the United States it has been inevitable in the past that the output from the mines in Chile should be disposed of away from the domestic market, and much of it came to Europe. The present situation, which is without precedent in the history of copper, leaves the South American production, which last year amounted to some 350,000 tons, "in the air," and short of facing up to payment of the U.S. import duty it is difficult to see what the producers can do about it. It is, of course, probable that a home will be found for some of this copper in Japan and, by arrangment with the British authorities, a part may come to Britain, while there is always the possibility that America may decide temporarily to allow free entry. To such a course there would, however, be strong opposition from some quarters.

A Downward Trend

One thing is abundantly plain, and that is the existence of a very large tonnage of unwanted copper, or perhaps it would be more correct to say unsaleable copper, for doubtless the Axis powers would be glad enough to have this metal could they lay hands on it. Already the march of events is compelling a downward trend in the New York copper market, where the price for export is well below 10¼ cents f.a.s., or a full cent per pound below the official domestic quotation. The situation certainly contains sinister possibilities from the point of view of the copper producers, and one can visualise the possibility of the world price of copper falling below that ruling in this country. In that event, would the British Government consider making a bulk purchase outside Empire sources of supply in order to lay down a special reserve? Such a course is at least possible, and the dollar credits which will be accumulated as a result of the U.S. Government's buying programme in tin would facilitate the financing of such a deal. How far the decline in the American export price can go is entirely a matter of conjecture, but it would seem to be limited in the first place by the extent to which South American copper succeeds in getting into consumption. At the worst, this copper from Chile and Peru would presumably be on offer at about 4 cents per lb. under the U.S. domestic price, but such a wide spread is unlikely, if only because in the process of arriving at such a desperate state of affairs, the American home market would have given way seriously, too.

What may well happen is curtailment of output, and it will be remembered that this was under consideration in America during the early part of this year, when business in the States was so slow. At that time, of course, there was quite a good demand for export. Now the position is very different, but, in view of U.S. Government's plans for intensive rearmament, a reduction in production might not be regarded very kindly by the official eye. However, on the broad issue it would certainly seem that the American price will move to a lower level.

Processing and Surface Treatment of Aluminium Castings

(*Continued from page* 40.)

Sand-blast finishes produce pleasing matt effects on aluminium, but owing to the nature of the surface obtained, such finishes are liable not to be permanent unless treated at once with clear varnish or lacquer to prevent the absorption of grease from the fingers and contamination by dust. Instead of being varnished, the work may, if required, be anodically oxidised.

Modifying Effects Obtained by Sand-Blasting

A large range of effects may be produced by varying the nature and grade of the grit or shot used by experienced choice of nozzle size and control of blast pressure, and by careful regulation of nozzle distance and motion. The use of steel grit, particularly for exterior work, is not to be recommended, as minute particles of steel are certain to be driven into the surface of the aluminium, which will consequently become spotted later by local corrosion effects. Silica sand and silicon carbide are satisfactory media, grades between 40 and 200 being suitable, according to the fineness of the finish desired.

The blast pressure depends upon the superficial hardness of the casting, the type of alloy, the size of the surface to be treated, the size of the abrasive medium, the type of surface to be produced and the available pressure. Pressures of 30 to 50 lbs. per sq. in. are commonly used.

The characteristic chemical properties of aluminium and the chemical and physical properties of the oxide film upon its surface, are responsible for a number of successful chemical and electro-chemical finishes. The former will be dealt with first.

Surface Effects by Chemical Treatment

Castings may be frosted by etching for about a minute in a caustic soda bath, at a concentration of about 10 per cent. and at a temperature of about 90 deg. C. Work emerges from the soda bath covered with a film due to the addition elements in the alloy; the black film due to copper is removed, after thorough washing to remove excess soda, in the subsequent acid dip (66 per cent. nitric acid), but for high-silicon bearing alloys, the addition of about half to one per cent. of hydrofluoric acid to the nitric acid is necessary; such a mixed acid bath is very active and should always be employed cold, to prevent any staining.

After the final dip it is essential that all acid should be washed from the castings. Alternate hot and cold rinses are usually advisable, special attention being paid to interiors or porous areas which may cause entrapping of acid.

Frosted finishes of this type are not permanent unless they are suitably protected by lacquering or anodic oxidation. The special etching effects obtainable on unalloyed aluminium are not, in general, obtainable on alloyed castings and will not, therefore, be considered here.

Surface Coatings by Chemical and Anodic Methods

Films produced by the "Alrok" or "MBV" processes may be obtained on aluminium alloy castings. These processes consist of straightforward chemical treatments designed to yield a moderately heavy film, which, whilst not so hard or resistant as the true anodic film, possesses many valuable applications, being, for example, capable of absorbing chemical inhibitors such as dichromates, dyes (although the colours obtained are found to be less brilliant than those given by anodic films), and oils. It furthermore forms an ideal base for painting, and gives excellent keying effects.

Some light-alloy castings may be anodised, one of the sulphuric-acid processes being most suitable for the purpose. Chromic-acid electrolytes are not only less generally satisfactory for cast work, but on some alloys are entirely useless. Those alloys containing notable quantities of heavy metals, however, yield as a rule non-uniform films of poor mechanical properties and less attractive colours, such films being of little decorative or utilitarian merit.

Production of Dyed Anodic Films

As in the case of other forms of aluminium, the anodic film obtained on castings (more especially those of lower alloy content) may be dyed by one or other of the available techniques suitable to the work in hand. Considerable skill is required to obtain really uniform effects on castings, and colour-matching, always a difficult process, is immeasurably complicated by the tendency of the surface properties of castings to vary with the slightest change in casting conditions, etc. Surface imperfections are particularly harmful where high-quality anodised or anodised-and-dyed finishes are called for.

Full knowledge of the conditions under which the casting is to be used should be available before any given treatment schedule is undertaken. Similarly, fullest details should be supplied to the anodising concern, if the work is to be done outside; many variations of treatment are possible, some more appropriate to particular alloys and fields of application than others.

Provided that they are sufficiently sound at the surface, aluminium-alloy castings may be successfully treated for decorative and protective purposes by electro-deposition. For the purpose of this account, attention will be limited to chromium plating, but it should be understood that most other metals may be deposited with equal facility.

Electro-Deposition of Chromium

Although chromium may be deposited direct on to aluminium, more satisfactory results are, in general, obtained by deposition on an undercoat of buffed nickel. In practice one successful procedure involves first the cleaning of the work in one or other of the recognised alkaline cleaners (*e.g.*, sodium carbonate 1 to 3 oz. per gallon, with trisodium phosphate 1 to 3 oz. per gallon). After cleaning, the work is rinsed in cold water and then dipped in 5 per cent. hydrofluoric acid, being again subsequently rinsed. In view of the strongly acid etching treatment which now follows, it is sometimes suggested that this preliminary acid dip be dispensed with.

The etching process is designed to produce a surface on the aluminium of such properties that the electro-deposit will readily adhere. A suitable composition contains 3 parts of strong nitric acid and 1 part of hydrofluoric acid (48 to 50 per cent.) and is used at about 30 deg. C. The time of treatment ranges from a minimum period for die-castings of 15 sec. to a maximum of 120 sec. for sand-castings. The dipping conditions are critical and should be regulated carefully according to an established schedule for given work. After dipping, the work is once again thoroughly rinsed before transference to the nickel bath.

Composition of Nickel Bath

A wide variety of bath compositions has been put forward as particularly suitable for aluminium alloys, and marked preferences appear to be shown for one or another particular process by electro-depositors in Europe and the United States of America. Good results, however, are yielded by the following composition: nickel sulphate 45 ozs. per gall., nickel chloride 2.28 ozs. per gall., boric acid 4 ozs. per gall. To overcome a tendency to pitting, intermittent addition of hydrogen peroxide (0.053 oz. per gall. of 30 per cent. peroxide) are made to the bath during operation; but excess is to be avoided as it has an embrittling effect on the deposit.

The bath is used at a temperature of 60 to 65 deg. C., with a current density of 30 amps. per sq. ft. The *p*H of the bath should be maintained at 2.0 to 2.5.

A fine matt deposit is obtained which readily buffs to a high finish. It is more than likely that the deposit will be intended chiefly for interior use; however, where moderate exposure to weather is likely to occur (as in automobile fittings, for instance) a minimum thickness of 0.001 in. of nickel should be called for. The plating technique described may be adapted for continuous automatic deposition of bright nickel upon aluminium in the cast and other forms.

Nickel deposited in the manner described here may form the basis for any other deposits, including chromium, which are applied in the usual way from baths of normal composition. Only in the case of strongly alkaline baths is a little extra care desirable.

A special plating process has been evolved for the electro-deposition of relatively heavy films of tin directly from an alkaline tin bath on the skirts of cast aluminium-alloy pistons. This procedure is adopted to minimise wear, and was formerly achieved by a plain dipping process which, however, in common with all such processes, yielded a coherent film of little more than molecular thickness.

In addition to the electro-deposition of metals in their customary form, procedures are available for depositing upon aluminium alloys special films, such as black nickel and chromium. For details regarding alternative systems of cleaning and pre-treating light-alloy castings prior to plating, reference must be made to the very ample literature on the subject.

Certain fallacies are still extant regarding the permanence and strength of adhesion of electro-deposits on aluminium. In this regard it is doubtful whether deposits correctly applied on aluminium alloys are in any way inferior to those on heavy metals. They are usually to be seen on metal intended for interior use, but the reasons for this do not rest upon shortcomings in the deposit itself. Furthermore, an incipient tendency to regard anodic treatment as an alternative to, or competitor of, electro-deposition, is entirely fallacious; the processes are complementary and not antagonistic.

Very little work has been done as yet on the production of deposited metallic films on aluminium-alloy castings by means of the metal spraying pistol. Aluminium-magnesium alloys appear to be the only metals so far employed for this particular purpose, which is solely to give increased corrosion resistance.

Procedure for Painting

The successful application of painted and lacquered coatings to aluminium-alloy castings, except when intended solely for decorative effect, demands the observance of a fairly rigid routine if maximum protective effect is to be secured. Provided that the surface of the metal is perfectly clean and grease-free, no troubles due to non-adherence or to unduly rapid flaking and blistering need be anticipated.

Degreasing is best carried out by the use of solvent vapour degreasers, followed by special

For High Quality Castings

The increasing demand for high-strength close-grained iron castings calls for improved metal. In comparison with the accepted standards of the past, the modern high quality casting requires lower total carbon and phosphorus, with a closer range in silicon. The Ironfounder can now meet this demand at a reasonable cost by the use of Stanton-Dale Refined Pig Iron.

Stanton-Dale is a pig iron of low total carbon, the graphitic carbon being uniformly distributed and of fine curly-flake formation. The close structure ensures remarkably high strength with good machineability, and Tensiles of 16 to 20 tons can readily be obtained when a proportion of Stanton-Dale Iron is introduced.

The use of this iron avoids the irregularities in structure which are sometimes observed when steel scrap has formed part of the charge.

The correct grade of Stanton-Dale Iron to use depends on the type and class of castings to be made. The Stanton Technical Service is available to advise on suitable mixtures.

Total Carbon from 2.6 per cent. upwards. *Analysis to individual specification as required.*

STANTON-DALE
REFINED PIG IRON

The Stanton Ironworks Company Limited, Near Nottingham

The Largest Producers of Foundry Pig Iron (for Sale) in Great Britain

alkaline (phosphate or silicate) degreasers, or, better still, by the special acid cleansers containing phosphoric acid which have recently appeared on the market. If the work is virtually clean to start with, treatment by solvent vapour degreasing may be omitted. Similarly if the casting is anodised or treated by the "Alrok" or "MBV" process, a fine keying surface is automatically provided for the paint, and if in either case the oxide film has previously been treated with chromate, maximum protection of the metal is assured.

Attempts to overcome deficiencies in the cleaning process by providing a roughened surface by snagging or (even worse) by sand-blasting, under the mistaken impression that an all-round improved adhesion is obtained, are misguided. Such practices, as might be expected, diminish the corrosion resisting powers of the basis metal.

Paints may be applied by brushing, dipping, spraying or roller coating; the procedure selected must depend upon the equipment available, the nature of the casting and, to some extent, the type of paint used. In what follows, it will be assumed that maximum corrosion protection is aimed at.

The procedure adopted for painting should be rigidly fixed with regard to the conditions the coating is designed to encounter. The basis of success lies in the choice of a suitable priming coat which may or may not contain an inhibitor, although the presence of the latter agent is most strongly to be recommended, being essential for extreme conditions. Zinc chromate is universally recognised as the best material in this regard, and may constitute the entire bulk of the pigment in the primer. Other properties desired in the priming coat are those normally called for; namely, good adherence, good impermeability to moisture and common gaseous corrosive agents in the air, and, of course, drying with such a surface that maximum anchorage is provided for the finishing coat.

Aluminium-Pigmented Priming Coats

For less severe conditions, aluminium-pigmented paints may be used, which comply with the bulk of the requirements set out above. Care should be taken, however, that the correct grade of aluminium paint is selected for this type of work; qualities suitable for wood may not necessarily prove satisfactory on a cast aluminium-alloy surface. As to the media employed in primers, long-oil varnish or a synthetic-resin varnish vehicle are suitable for aluminium-pigmented primers, whilst for the zinc-chromate type, the synthetic-resin-base vehicle has proved ideal.

Where special finishing coats are required (bituminous paints, for instance), it may be advisable to select a primer which is specially suited to the occasion (*i.e.*, in this case a bituminous primer).

Finishing Media

For finishing coats, oil-base paints, long-oil varnishes, synthetic-resin-base varnishes or enamels, variously pigmented, are all adaptable for the treatment of light-alloy castings. Nitrocellulose lacquers possess rapid air-drying qualities and, particularly when pigmented with aluminium, are notably stable to sunlight. With all lacquers, care should be taken to see that they are used in conjunction with a suitable primer; as on other occasions, advice may well be sought from the suppliers of such finishes before the work is undertaken.

Clear finishes must be stable to light, and for this purpose a variety of reliable synthetic-resin-base lacquers are available which do not yellow even after prolonged exposure to sunlight.

A word of caution is necessary in connection with the painting of light-alloy castings on boats and ships. Under no circumstances should anti-fouling paints be applied to light-alloy surfaces unless it is known with certainty that they have been found safe for the purpose. Many such paints contain mercury or copper compounds which, in the presence of sea water particularly, may initiate violent corrosion of the aluminium surface.

Vitreous Enamelling

A limited use has been made of vitreous enamel finishes on light alloy castings but, owing to the high firing temperature commonly required, their use has not proved of much practical value. Low-temperature vitreous enamels are too readily attacked by acid media and even by boiling water. The powder spraying pistol, in conjunction with vitreous enamels of special composition which are sprayed on to a sand-blasted surface preheated to about 200 deg. C., has yielded very promising experimental results.

By means of this instrument, too, coatings of rubber, bitumen, and certain synthetic resins may be applied by techniques involving the use of dry, solvent-free powders which yield, if required, very heavy, non-shrinking, highly impermeable coatings. In another system a very viscous paint is sprayed by means of a special pistol, in which it is heated up by passing through a "low-temperature" flame. The object of these treatments is to obtain a degree of corrosion resistance in conjunction with mechanical strength not readily attained by ordinary paint of lacquer coatings.

In conclusion, reference must be made to patented processes designed to produce extremely massive rubber facings on metal components. Special techniques have been developed to promote adhesion between the metal and the rubber. The processes, which are mostly applicable to light-alloy castings, find use in the production of special shock-resisting or vibration-damping parts for aircraft and automobiles.

Reducing Pattern and Core-Box Maintenance

Difficulty is often experienced where sections of patterns and core-boxes have to be frequently screwed together and removed, as it is always found that the hole in the wood that takes the screw gradually wears and allows a varying amount of play, which, of course, leads to an inaccuracy in either the pattern or the core. Many large patternmaking firms are now employing a preparation known as "Philplug," which is manufactured by Philplug Products, Limited, Aintree Road Works, Perivale, Greenford, Middlesex. This material is normally employed as a wall-plugging material, but lends itself for use in pattern and core-box work, and very largely overcomes the trouble mentioned above.

The material is a plastic asbestos compound, and to use it for the above-mentioned purpose a hole slightly larger than the screw should be bored in the wood. This hole is then packed with "Philplug" and the screw introduced. The plastic material hardens under pressure, so that the action of inserting the screw hardens the material sufficiently for the load on the screw to be applied immediately. There is no need to wait for the material to harden. The screw leaves in this material an accurately moulded thread. The screw can be withdrawn and inserted as often as necessary, and the hole does not wear. It further ensures that the sections of the pattern or core-boxes invariably fit together accurately every time.

On existing patterns or core-boxes, where the screwed hole has worn badly, all that is necessary is to fill the hole with Philplug and again insert the screw. This takes up the wear that exists and again provides an accurate hole.

Book Review

History of the Cast Iron Pressure Pipe Industry of the United States of America. By H. J. Noble. Published by the American Branch of the Newcomen Society.

The origin of this book was an address which the author delivered at a dinner held in Alabama under the auspices of the local committee of the Newcomen Society. The story disclosed is in every way complete. Due prominence is given to the beginnings in Europe, and especially in England, to which country credit must be given for the initial commercial development. Moreover, English craftsmen played a leading part in the technical development in America. One noteworthy contributor was George Peacock, who introduced the vertical casting pipe pit in 1852. Apparently, this method had been perfected and patented (in 1846) by D. Y. Stewart of the Links foundry of Montrose. Peacock was born at Stockton-on-Tees in 1823 and went to America with Ericson to design and build the "Monitor" that was to engage the "Merrimae." He is credited with the invention and perfection of the drop pattern now used in machine moulding and the application of core arbours to green-sand moulding of fittings. He also invented a collapsible core bar, used in vertical casting.

Another English pioneer in the American cast-iron pipe industry was John Firth, a Yorkshireman born in 1820, whose efforts challenge the claim of Peacock to be the pioneer of the pit for the vertical casting of pipes, as he arrived in America in 1820.

The history of the firm of R. D. Wood & Company, of New Jersey—created in 1805—will be especially interesting to the older members of the Institute of British Foundrymen, as Mr. Walter Wood, a nephew of the founder, was as well known in London as in America. He lived to a ripe age and retained to the last an enthusiasm for international technical co-operation in foundry matters, and to further this object allowed neither expense nor personal inconvenience to deter him.

The history concludes with some notes on the development of the de-Lavaud and the sand-spun systems. The author has given a very readable account of a development which is of international interest.

Canadian Iron Ore

The development of the hematite iron-ore deposits underlying Steep Rock Lake, 135 miles west of Fort William in north-western Ontario, has progressed considerably in recent months, according to a report in the "Mining Congress Journal." This is true both in the exploration of the ore bodies by geophysical methods and core drilling and in the sinking of the shaft alongside the lake, from which crosscuts will be driven into the ore body which is now definitely outlined over an area more than 3,500 ft. long and ranging in width from about 150 to 300 ft.

The vertical three-compartment shaft has passed the 800-ft. mark, where a station has been cut and a crosscut toward the ore has been begun. The shaft will be continued down to 1,200 ft. It is planned to carry the crosscut out 1,200 ft. and then cut a diamond-drill station, from which drill holes will be fanned out to cut through the ore body at various points; meanwhile, the crosscut will be continued out to the ore (about 800 ft. farther). The owners hope to reach the ore next month.

In a recent advertisement, the company announced plans for initial production on a basis "of at least 2,000 tons daily in 1940," but this time limit is regarded as optimistic by some qualified observers, who do not expect production to be under way before 1941.

" PIGS IS PIGS "

There are, unfortunately, Founders who say " What's in a Name," and who, surprisingly enough, manage to produce excellent castings without the assistance of our special pig irons. But there are a great majority who know that the name of Warners is a guarantee of dependability, of accuracy of analysis and of soundness of casting and that the high-duty irons required to-day are more easily produced by the use of Warner pig irons. To such Foundry men "Pigs is Pigs"—

BUT

Warner's IS Warner's

May we have your enquiries ?

WARNER AND CO., LTD., CARGO FLEET, MIDDLESBROUGH

The Week's News in Brief

Trade Talk

JOHN G. STEIN & COMPANY, LIMITED, of Bonnybridge, Stirlingshire, are giving holiday pay to relatives of soldier employees who have been reported missing.

THE ANNUAL GENERAL MEETING of the Keighley Association of Engineers was held last night, when the chairman (Mr. J. W. Rice) delivered his presidential address.

THE COLLECTION OF ALUMINIUM WARE from the public for use in aircraft manufacture will close on Saturday. It is intimated that a further call will later be made for aluminium still available in the country, owing to increasing needs.

THE DOVER ENGINEERING WORKS, LIMITED, Dover Iron Foundry, Bridge Street, Dover, has removed the whole of its personnel and portable plant to the Watford Foundry Company, Limited, By-Pass Road, Watford, Herts. Correspondence for the former should be addressed care of the latter.

THE MINISTER OF AIRCRAFT PRODUCTION has made the Control of Magnesium (No. 1) Order, which came into force on Tuesday of this week, providing that magnesium and magnesium alloys, whether unfabricated or in the form of billet, block, powder, slab or stick shall not be bought, sold or used except under licences. Inquiries should be addressed to the Ministry of Aircraft Production Light Metals Control, Southam Road, Banbury.

FOLLOWING an examination in London last month, in which boys from public and secondary schools took part, F. M. Turner (Birkenhead School), D. A. MacWilliam (King's College School) and G. E. Mee (Chigwell School) have been awarded engineering scholarships by R. A. Lister & Company, Limited, Dursley. They will be given a 4½-years' course of training in the machine shops and drawing offices, and during that period will be paid salaries which start at £135 a year.

TO ASSIST professional men who in the present emergency encounter technical problems in applied physics of which they have not had previous first-hand experience, it has been decided to extend the facilities of the Institute of Physics' panel of consultants. Through this medium inquirers are put into touch with those physicists most likely to be able to offer immediate practical suggestions in any particular case. In the first instance the contact is quite informal; subsequent arrangements are a matter for private agreement between those concerned. The subjects which can be dealt with cover all branches of physics, both pure and applied. Inquiries about the scheme should be addressed to the Secretary of the Institute of Physics, the University, Reading, Bucks.

THE CONTROL OF TINS AND CANS (NO. 1) ORDER, 1940, which operates as from July 23, prohibits the use of tinplate and steel sheet in the manufacture of containers for a wide range of commodities, comprised mainly of food products and cosmetic and toilet products. The Order also bans the use of tinplate or sheet in the manufacture of advertising novelties, showcards and certain kindred articles, and lists approved sizes for tins for packing certain commodities. Some approved sizes will be for use only between manufacturer and retailer, being returned to the former when empty. As existing stocks are exhausted, alternative containers made from salvaged paper will make their appearance. The Order was signed by the Minister of Supply following recommendations made by the Tinplate Economy Committee. The restrictions and prohibitions it introduces will, it is estimated, save between 40,000 and 50,000 tons of tinplate and sheet a year.

Ersatz Rolling-Mill Bearings

The latest German experience with substitute materials for rolling-mill bearings, such as hard wood, cast iron, light metals, steel and plastic compositions, is surveyed in "Zeitschrift des Vereins deutscher Ingenieure" by E. ROHDE. Synthetic resin bearings require a special design in view of the lubrication necessary, as well as cooling and other measures to prevent excessive wear.

Personal

DR. MAURICE COOK, M.Sc., of Perry Barr, Birmingham, has been awarded the degree of D.Sc. of Manchester University.

SIR WILLIAM GRAY, who has been elected to a seat on the North-Eastern board of Martins Bank, Limited, is chairman of William Gray & Company, Limited, shipbuilders, of West Hartlepool.

MR. H. W. G. HIGNETT, B.Sc., has joined the staff of the Mond Nickel Company, Limited, with whom he will be engaged upon the development of the welding of nickel and nickel alloys. He has for the last ten years been in the service of the Aluminium Plant & Vessel Company, Limited.

MR. G. E. FRANCE, managing director of August's, Limited, of Halifax, is chairman of both the Foundry Equipment and the Furnace Export Groups. Mr. K. W. Bridges is the secretary of the two Groups. His address is Room 242, Grand Buildings, Trafalgar Square, London, W.C.2.

MR. W. L. STEPHENSON, chairman of F. W. Woolworth & Company, Limited, has been appointed by the Minister of Aircraft Production to be Director-General of Equipment in the Ministry. Mr. Stephenson, it is understood, will be concerned with additional fittings to machines after assembly, such as radio, instrument panels and other accessories.

MR. WILLIAM OLIVER and Mr. J. T. Hynan, patternmaker and night-watchman respectively at the Railway Foundry at Newton Heath, Manchester, of Matthew Swain, Limited, have each completed 50 years' service with the firm. To celebrate the occasion, there was a gathering of workpeople recently, when Mr. Matthew Swain presented a gold watch and £50 in treasury notes to each. From the workpeople Mr. Oliver and Mr. Hynan each received a chiming clock and a cigarette case.

Obituary

MR. F. S. BURNLEY, a director of Isaac Braithwaite & Son, Engineers, Limited, Kendal, died in London on July 13.

MR. ALEXANDER CORRIN WALBER, managing director of W. A. Walber & Company, Limited, Victoria Street, London, S.W.1, died on July 14, aged 39 years.

MR. RALPH MODJESKI, world-famous bridge engineer, died in Los Angeles recently at the age of 79. He was chief engineer or consultant for bridges costing about $250,000,000.

THE DEATH occurred suddenly on Thursday last of Mr. Alexander Barnetson, who for 35 years was foreman with the North British Locomotive Company, Limited, of Springburn, Glasgow. He was one of the founders of the West of Scotland Association of Foremen Engineers, of which he was a Past-President. Mr. Barnetson was 74 years of age, and resided at Lenzie, having retired nine years ago.

MR. ALBERT CHARLES JENKINS, who has died at Jarrow at the age of 72, was manager of the Hebburn Shipyards of Palmers' Shipbuilding & Iron Company, Limited, for several years. He retired seven years ago after 44 years' service with the firm. In the Great War he was complimented for the repairs carried out to H.M.S. "Lion" after the battle of Jutland. The vessel could not be docked on the Tyne and a specially-designed coffer dam was built around the ship so that repairs could be carried out below the water line.

Applications for Trade Marks

The following list of applications to register trade marks has been taken from the "Trade Marks Journal":—

"DANARM"—Machine saws, sawing machines, etc. T. H. & J. Daniels, Limited, Lightpill Ironworks, Stroud, Glos.

"POLYVIC"—Insulating material. I.C.I. (PLASTICS), LIMITED, Wexham Road, Slough, Bucks.

New Companies

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

Ryecroft Electric, Limited, Smith Street, Ashton-under-Lyne—Capital £10,000. Electrical and general engineers, etc.

Thomas Taylor & Sons (Leicester), Limited, Gladstone Street, Leicester—Capital £2,000. Engineers. Directors: F. W. and C. S. Taylor.

Todd Bros. (St. Helens & Widnes), Limited, Canal Bank West, St. Helens—Capital £75,000. Iron and steel manufacturers. Directors: M. and W. H. Todd.

E. Pass & Company, Limited, Station Works, Denton—Capital £21,000. Gas and water engineers, tool makers, etc. Directors: F. Cooke, P. Hibbert and F. L. Cooke.

Contracts Open

Aberdeen, July 27—Cast iron, malleable iron, drain pipes, etc., for three months from August 1, for the Town Council. Mr. T. F. Henderson, city engineer, City Engineer's Office, Town House, Aberdeen.

Huntingdon, July 27—3-in. and 4-in. dia. iron pipes, valves, hydrants, etc., for the Rural District Council. Pick, Everard, Keay & Gimson, engineers, 6, Millstone Lane, Leicester. (Fee £4 4s., returnable.)

Wolverhampton, July 29—Pumping equipment and machinery, for the Sewerage Committee. The Borough Engineer, Town Hall, Wolverhampton. (Fee £2 2s., returnable.)

Patent Specifications Accepted

The following list of Patent Specifications accepted has been taken from the "Official Journal (Patents)." Printed copies of the full Specifications are obtainable from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each. The numbers given are those under which the Specifications will be printed and abridged, and all subsequent proceedings will be taken.

521,574 WESTERSCHULTE, L. Low-frequency induction smelting furnaces.

521,609 JOHNSON, P. G. Clamping arrangements for pipe joints.

521,610 DEUTSCHE EISENWERKE AKT.-GES. Manufacture of centrifugal castings.

521,661 MACDONALD, J., and G.W.B. ELECTRIC FURNACES, LIMITED. Furnaces.

521,689-90 MERLE, J. M. Apparatus for making products derived from molten metal.

521,701 BRASSERT, H. A., and BRASSERT & COMPANY, LIMITED, H. A. Manufacture of steel by the Bessemer process.

521,824 DEUTSCHE EISENWERKE AKT.-GES. Centrifugal casting of metals.

521,858 HERAEUS-VACUUMSCHMELZE AKT.-GES. Ironless induction furnaces.

521,487 BAILLOT, A. Means for utilising pulverised coal for heating furnaces.

522,168 CRONING, J. Manufacture of moulds for casting.

Castings from Municipal Foundries

Speaking in the House of Commons recently, MR. DOBBIE asked a question regarding the steps taken in order to facilitate the supply by a local authority of iron castings to a firm in its area in order to assist the latter in the execution of contracts with the Ministry of Supply.

MR. H. MORRISON, replying, said the firm in question needed the castings and the local authority was prepared to supply them, subject to the question of the legality of using its foundry for other than municipal purposes. In order to remove any doubt as to this he issued a direction under the Defence (General) Regulations requiring the corporation to supply iron castings to the firm in question in order to assist it in the execution of contracts with Government Departments. He would be prepared to take similar action in other cases where such action was justified. The power to give directions to local authorities under the Defence Regulations was possessed by a number of Ministers and authorities besides the Minister of Supply.

for 'longer life' . . . .

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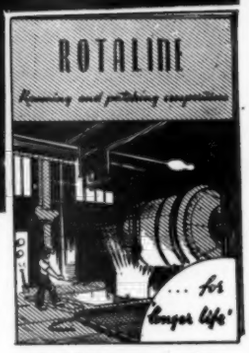

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ROTALINE has a base of high quality calcined silica rock and it is bonded with other suitable refractory materials. The satisfactory results obtained in numerous furnaces throughout the country substantiate the outstanding quality of this material. Rotaline is supplied in a suitable condition for ramming and no mixing or treatment is necessary before use.

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Raw Material Markets

An appeal, signed by the heads of the munitions supply departments of the Government, has been sent to the managements of some 9,000 firms working for the Government on war materials production, asking that the maximum use be made of skilled labour under their control. Many iron and steel concerns are included in this appeal and if it is possible for works to make any beneficial changes in the organisation and utilisation of their man-power these will be promptly carried out.

Ironworks continue to place heavy tonnages of pig-iron at the disposal of priority consumers, but it is not possible, unfortunately, to assist other users to the full extent of their wishes. Both iron and steel makers are able to enlarge their production as a result of the increased supplies of scrap now reaching them and further expansion is expected to be attained. Light-castings foundries are gradually playing a fuller part in the war effort, but much more work is required before the trade is able to achieve maximum operations.

Pig-Iron

MIDDLESBROUGH—Iron-castings makers in the Cleveland district are mostly very busy on Government specifications, but some of the light foundries would welcome additional orders, as, on the whole, the amount of work so far placed in connection with the war effort has been insufficient to keep them working full time. Heavy engineers, on the other hand, are working to capacity. Most of the local ironworks are producing iron for the steel furnaces, so that foundries are obliged to acquire their needs from the Midlands. A firmer tone in the hematite market is reported and consumers' requirements appear to expand week by week. Consequently, supplies are having to be distributed with the utmost care. While the chief demand is for the higher grades, other descriptions of hematite are in full request.

LANCASHIRE—Consumption of pig-iron is maintained on a heavy scale and large tonnages are being called for from Derbyshire and Staffordshire makers. Deliveries generally are satisfactory, but priority users are receiving first consideration at all times. Government departments are keeping the speciality engineering trade fully occupied, but short time is still apparent among certain light-castings manufacturers. Hematite is moving away freely, West Country material being largely used in this area.

MIDLANDS—The bulk of the iron available in this area is being reserved for works engaged on Government contracts, as there is little, or no, surplus after these substantial requirements have been met. Light-castings makers and other users of high-phosphorus iron are finding some difficulty in obtaining their full requirements, as the output of this iron has been restricted for some considerable time past, and now, owing to less low-phosphorus iron and hematite being available, demand for high-phosphorus iron is expanding and reduced quantities are offering to firms outside the priority lists. Special irons are in very strong demand by high-grade castings makers, but every effort is being made to keep works supplied, as these irons enter largely into the production of armaments.

SCOTLAND—The present supply of pig-iron is little more than sufficient to meet day-to-day requirements, and stocks at the consumers' works have largely been absorbed. While the heavy engineering concerns continue to work at a very high rate, conditions in the light-castings trade are still unsatisfactory. There is a steady improvement to be recorded, but the amount of Government work is inadequate to counteract the falling off in peace-time orders. Foundries are obtaining their needs from the English Midlands, no iron having been despatched from the Cleveland district for a considerable time past. Fixed prices are 118s. 9d. for No. 3, f.o.t. Falkirk, and 121s. 9d. per ton, f.o.t. Glasgow, both less 5s. rebate.

Coke

Contract deliveries of foundry coke continue to be made quite liberally, and useful reserves are being built up at consuming works. Forward business is transacted on the basis of the price ruling at the time of delivery. The current quotation is 55s. 6d. per ton, delivered to Birmingham and Black Country stations, but a further advance in this minimum price may be intimated by the Control authorities at any time.

Steel

While the steel industry's first duty is to supply the requirements of the fighting forces, it appears likely that heavier tonnages of finished products of certain descriptions will be made available for the export trade. It must be assumed, therefore, that deliveries of steel on account of Government contracts are satisfactory; although no details of the steel output of the United Kingdom are released for publication, one thing is certain—works have never produced larger tonnages than is the case at the present time, and the trend is still in the right direction. The licensing system does not allow consumers on non-essential work much latitude, but it is appreciated that the export trade is, in the circumstances, of vital importance, and every effort will be made to despatch larger supplies overseas. Very heavy tonnages continue to be absorbed, and all descriptions are in substantial request. Distribution, of course, is still in the hands of the Control, and the makers' responsibilities end at the production stage. Some 40,000 to 50,000 tons of tinplate and sheet steel are expected to be saved through an Order made on Tuesday by the Ministry of Supply involving restrictions and prohibitions on the use of tin for certain containers for cigarettes, boiled sweets, cosmetics, etc. The metal will now go to the manufacture of shells.

Scrap

Very considerable supplies of scrap iron and steel have been passed on to the consuming works as a result of the collection schemes, but the Minister of Supply, in making an Order for the compulsory acquisition of scrap by local authorities, states that the time has gone by for raising queries and examining difficulties before collection schemes are put into operation. The Order applies to all local authorities with a population of over 10,000. This is a wise move on the part of the Ministry, for, while certain authorities have exceeded expectations in this connection, others, especially in rural areas, have not put sufficient drive into their efforts. Too much time has also been wasted in sorting, classifying and preparing for use in the furnaces the scrap metal obtained. Steady deliveries are reaching users, but there has been no opportunity for stocking as yet.

Metals

The London tin market has been on the quiet side of late. Consumption not only in the United Kingdom, but throughout the world, is on a very heavy scale, and it now seems likely that the supply position will become increasingly stringent, despite the additional production recently sanctioned by the International Tin Committee. In the United States, consumption is maintained, but the near approach of the holiday season there will inevitably tend to reduce the rate for a time.

London Metal Exchange tin prices this week have been as follow:—

Cash—Thursday, £266 10s. to £266 15s.; Friday, £265 15s. to £266; Monday, £266 10s. to £266 15s.; Tuesday, £267 to £267 5s.; Wednesday, £266 15s. to £267.

Three Months—Thursday, £265 to £265 5s.; Friday, £264 10s. to £264 15s.; Monday, £265 10s. to £265 15s.; Tuesday, £266 to £266 5s.; Wednesday, £266 10s. to £266 15s.

The text of the agreement between the U.S. Government organisation, Reconstruction Finance Corporation, and the International Tin Committee designed to furnish America with reserve stocks of tin has now been issued. The Metal Reserve Company (created by the Corporation) undertakes to purchase all the tin offered in accord with the agreement and to hold stocks acquired for a period of not less than three years from January 1, 1940. Afterwards it may be liquidated provided notice is given and that not more than 5 per cent. with a maximum of 5,000 tons is sold in any three months' period. The tin may be released for use of the U.S. Government or to private consumers in the event of a national emergency. The agreement may be terminated when not less than 75,000 tons have been purchased and retained as a reserve. As previously stated, tin is to be bought at 50 c. per lb.

Because of the inability of their representative committee to function in Brussels owing to present circumstances, the Belgian Congo tin producers have decided to constitute a tin committee with headquarters at Elizabethville, Belgian Congo. The object of the committee will be to assure the control of tin output and to protect producers' interests.

The requirements of the essential industries largely account for the supply of copper available in this country, and consumption in this respect is very substantial. The supply position must be considered quite satisfactory and should remain so in the future. The American Government are in the market for copper to some extent, but, in view of the heavy productive capacity of the domestic trade, it is unlikely that the U.S. Government will accumulate substantial reserve stocks.

Although care has to be taken in the allocation of supplies of high-grade zinc, the spelter position in this country is not unsatisfactory and the munitions producers are getting large deliveries. It seems likely, too, that the British Government will take over some of the French orders for high-grade metal placed in the United States, so that British works may shortly receive fuller deliveries.

In addition to meeting the full needs of the defence requirements of lead, good tonnages are being released for export and home ordinary industrial uses. The American Bureau of Metal Statistics announces that stocks of refined lead in the United States at the end of June totalled 55,300 short tons, compared with 63,000 tons at the end of May. Production was 42,300 tons (46,300 tons) and despatches 49,900 tons (46,900 tons).

Reports and Dividends

Allied Ironfounders, Limited—Dividends from subsidiary companies for the year to March 31, after deduction of income tax, £100,352; interest on deposits and investment income, less tax and income tax recovered, £14,882; brought in, £160,918; dividend on the 7 per cent. cumulative preference shares, £41,773; ordinary dividend of 5 per cent., £53,372; carried forward, £178,197.

F. H. Lloyd & Company, Limited—Net profit to March 31, £38,201; brought in, £21,641; preference dividend, £1,500; ordinary interim of 3 per cent., £4,875; final dividend of 7 per cent., £10,938; reserve for taxation, £3,000; reserve for contingencies, £7,000; general reserve, £5,000; A.R.P., £5,000; carried forward, £22,530.

Bradley & Foster, Limited—Trading profit for the year ended March 31 last, £23,338; taxation, including N.D.C., £9,041; to depreciation reserve, £2,453; brought in, £7,029; to general reserve, £5,000; interim dividend on the ordinary shares of 4 per cent., £1,998; final dividend on the ordinary shares of 4 per cent., plus a bonus of 2 per cent., £2,882; carried forward, £8,994.

Whessoe Foundry & Engineering Company, Limited

The present year marked the completion of 150 years since the inception of the business in 1790, and 20 years since the formation of the present company, said MR. HAROLD G. JUDD at the annual meeting of the Whessoe Foundry & Engineering Company, Limited. The production for the year constituted a record, the works having been fully occupied, mainly on work of national importance. The completion of the new welding shop, itself of welded construction, coupled with the installation of additional plant of the latest type, had put the works in a condition of the highest efficiency. They had continued to supply important plants for the cleaning and treatment of blast furnace, coal, and producer gas. They had also enlarged and improved the erection department, and had provided new equipment and methods for acceleration of such work.

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High-Pressure FANS FOR FOUNDRIES

- FORGE FANS
- CUPOLA FANS
- STEEL PLATE FANS

"Sirocco" High Pressure Fans have been designed for the comparatively high pressures which are necessary in connection with the supply of air blast to Forges and Cupolas, or for work of a similar character. The Fans are soundly constructed to give hard and continuous service with a minimum of attention.

MANUFACTURED IN A WIDE RANGE OF SIZES AND DESIGNS

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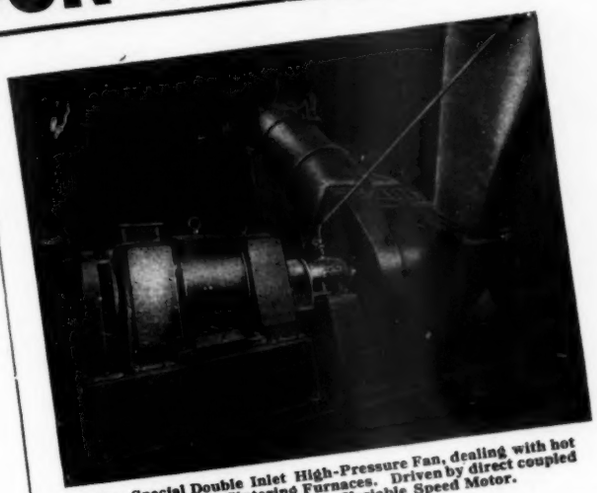

50-ins. Special Double Inlet High-Pressure Fan, dealing with hot gases from Spelter Sintering Furnaces. Driven by direct coupled 110 B.H.P. 440 Volt. D.C. Variable Speed Motor.

DAVIDSON & CO., LTD., SIROCCO ENGINEERING WORKS, BELFAST
LONDON · MANCHESTER · GLASGOW · NEWCASTLE · BIRMINGHAM · CARDIFF · DUBLIN · BRISTOL

Almost 60 years' experience is behind the trade mark "SIROCCO"

Use TITANITE *and Speed up war production*

The stone material for pattern-plates

- *Quickly and easily prepared*
- *Plates ready for use next day*
- *No expansion, cracking or contraction*
- *Has the strength and appearance of marble*
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- *Pattern Plates last for years*
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Time is the vital factor now in war production and Titanite is playing its part in many branches of aero and armament work by eliminating pattern-making delays and saving skilled labour,

THE CONSTRUCTIONAL ENGINEERING CO LTD

TITAN WORKS, BIRMINGHAM, 12

Telephone: MIDLAND 4753-4 Telegrams: "STRUCTURAL"

RAW MATERIALS—PRICE LIST

Wednesday, July 24, 1940

COPPER*

	£	s.	d.
Electrolytic	62	0	0
High-grade fire-refined	61	10	0
Fire-refined of not less than 99.7 per cent.	61	0	0
Do., do., 99.2 per cent.	60	10	0
Black hot-rolled wire rods	65	10	0

TIN

	£	s.	d.
Standard cash	266	15	0
Three months	266	10	0
Settlement	267	0	0
Official average Cash, June	273	12	10½
Do. Three Months, June	274	9	6
Do. Settlement, June	273	12	0

SPELTER*

	£	s.	d.
G.O.B. (foreign) (duty paid)	25	15	0
Do. (domestic)	26	10	0
"Prime Western"	26	10	0
Refined and electrolytic	27	5	0
Not less than 99.99 per cent.	28	15	0

LEAD*

	£	s.	d.
Good soft pig lead (foreign) (duty paid)	25	0	0
Do., do., (Empire and domestic)	25	0	0
English	26	10	0
Sheets, home	34	10	0
Do. export, f.o.b.	30	0	0
Pipes, home	34	0	0
Do. export, f.o.b.	30	10	0
Tea lead (nom.)		—	

ALUMINIUM

Ingots	£110
Wire, 10g.	nom.
Sheets	nom.
Circles, 20/24g.	nom.

ZINC SHEETS, etc.

	£	s.	d.
Sheets, 10g. and thicker, ex works	39	2	6
Rolled zinc (boiler plates), ex works	37	2	6
Zinc oxide (Red Seal), d/d buyers' premises	28	7	6

ANTIMONY

	£	s.	d.
English, 99%	98	10	0
Foreign Regulus, duty paid	99	0	0
Chinese, prompt shipment, c.i.f.	82 0 0 to 84	0	0

QUICKSILVER

Quicksilver, ex-w'hse London 57 0 0 to 60 0 0

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	3s. 0d.
Finished bars, 18% tungsten	3s. 10d.
Finished bars, 22% tungsten	4s. 4d.

Per lb. d/d buyers' works.

NICKEL SILVER, etc.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
to 10g.	1/6½ to 2/1½

with extras according to gauge.

Special 5ths quality turning rods in straight lengths, 1/5½ upwards.

* Maximum prices per long ton delivered to buyers' premises.

FERRO-ALLOYS AND STEEL-MAKING METALS

(all prices nominal)

	£	s.	d.
Ferro-silicon—			
25%	18	10	0
45/50%	21	10	0
75%	31	0	0
Ferro-vanadium—			
35/50%	15/6 lb. Va.		
Ferro-molybdenum—			
70/75% carbon-free	6/- lb. Mo.		
Ferro-titanium—			
20/25% carbon-free	1/9 lb.		
Ferro-tungsten—			
80/85%	5/1 lb.		
Tungsten metal powder—			
98/99%	5/2½ lb.		
Ferro-chrome—			
2/4% car.	—		
4/6% car.	47	0	0
6/8% car.	47	0	0
8/10% car.	—		
Ferro-chrome—			
Max. 2% car.	—		
Max. 1% car.	—		
Max. 0.5% car.	—		
70% carbon-free	—		
Nickel—99.5/100%	£190 to £195		
"F" nickel shot	175	0	0
Ferro-cobalt, 98/99%	8/9 lb.		
Metallic chromium—			
96/98%	3/9 lb.		
Ferro-manganese—			
76/80% loose	18	0	0
76/80% packed	19	10	0
Metallic manganese—			
94/96% carbon-free	1/9 lb.		

Per ton unless otherwise stated, basis 2-ton lots, d/d Sheffield works.

SCRAP*

	£	s.	d.	£	s.	d.
SOUTH WALES—						
Short heavy steel, not ex. 24-in. lengths	3	16	6 to	3	19	0
Heavy machinery cast iron			4	6	6	
Ordinary heavy cast iron			4	1	6	
Cast-iron railway chairs			4	6	6	
Medium cast iron			3	17	9	
Light cast iron			3	13	0	
MIDDLESBROUGH—						
Short heavy steel	3	14	3 to	3	16	9
Heavy machinery cast iron			4	11	3	
Ordinary heavy cast iron			4	8	9	
Cast-iron railway chairs			4	8	9	
Medium cast iron			3	19	0	
Light cast iron			3	14	0	
BIRMINGHAM DISTRICT—						
Short heavy steel	3	9	3 to	3	11	9
Hematite ingot mould			5	10	9	
Heavy machinery cast iron			4	11	9	
Ordinary heavy cast iron			4	7	0	
Cast-iron railway chairs			4	7	0	
Medium cast iron			3	19	9	
Light cast iron			3	14	9	
SCOTLAND—						
Short heavy steel	3	14	0 to	3	16	6
Heavy machinery cast iron			4	13	9	
Ordinary heavy cast iron			4	8	9	
Cast-iron railway chairs			4	13	9	
Medium cast iron			3	16	9	
Light cast iron			3	11	9	

* Delivered free to consumers' works in England and Wales. For deliveries of cast-iron scrap free to consumers' works in Scotland, the above prices less 3s. per ton, but plus actual cost of transport or 6s. per ton, whichever is the less. All prices: Plus 2½ per cent. dealers' remuneration: 50 tons and upwards over three months 2s. 6d. extra.

PIG-IRON*

N.E. COAST (d/d Tees-side area)—	
Foundry No. 1	123/-
„ No. 3	120/-
„ No. 4	119/-
Forge No. 4	119/-
Hematite No. 1	131/-
Hematite M/Nos.	130/6
N.W. COAST—	
Hem. M/Nos. d/d Glas.	131/-
„ d/d Birm.	142/6
MIDLANDS (d/d Birmingham dist.)—	
Staffs No. 4 forge	121/-
„ No. 3 fdry.	122/-
Northants forge	118/6
„ fdry. No. 3	119/6
„ fdry. No. 1	122/6
Derbyshire forge	121/-
„ fdry. No. 3	122/-
„ fdry. No. 1	125/-
Phosphorus 0.5% to 0.75%	129/6
Phosphorus 0.1% to 0.5%	132/6
SCOTLAND—	
Foundry No. 1, Grangemouth	119/9
„ No. 3, Grangemouth	117/3
Cleveland No. 3, Glasgow	123/-
„ „ Falkirk	120/-
Scottish hem. M/Nos. d/d	131/-
SHEFFIELD (d/d district)—	
Derby forge	118/6
„ fdry. No. 3	119/6
Lincs forge	118/6
„ fdry. No. 3	119/6
W.C. hematite	136/6
LANCASHIRE (d/d eq. Man.)—	
Derby fdry. No. 3	125/-
Staffs fdry. No. 3	125/-
Northants fdry. No. 3	123/6
Cleveland fdry. No. 3	125/-
Cylinder and Refined Irons	
North Zone	168/-
South Zone	170/6
Refined Malleable	
Birmingham and S. Staffs	165/6
Cold Blast	
South Staffs	217/-

* Prices of hematite and basic pig-iron, and of foundry and forge iron with a phosphoric content of not less than 0.75 per cent., are subject to a rebate of 5s. per ton under certain conditions.

SEMI-FINISHED STEEL

Re-rolling Billets, Blooms and Slabs.

	£	s.	d.
BASIC:			
Soft, u.t., 100-ton lots	10	10	0
Tested, up to 0.25% C.	10	15	0
Tested, 0.25 to 0.33% C.	10	17	6
Tested, 0.33 to 0.41% C.	11	0	0
Hard (0.42 to 0.60% C.)	11	17	6
„ (0.61 to 0.85% C.)	12	7	6
„ (0.86 to 0.99% C.)	12	17	6
„ (1% C. and up)	13	7	6
Silico-manganese	14	5	0
Free-cutting	12	10	0
SIEMENS MARTIN ACID			
Up to 0.25% C.	13	15	0
Case-hardening	14	12	6
Silico-manganese	14	10	0

Billets, Blooms and Slabs for Forging and Stamping.

Basic soft, up to 0.25% C.	12	2	6
Basic hard, 0.41 to 0.60% C.	12	10	0
Acid, up to 0.25% C.	14	5	0

Other Semi-products, etc.

Tin bars	10	7	6
Sheet bars	10	7	6
*Wire rods, soft basic	15	4	0
„ hard basic	18	12	6
„ free-cutting	17	12	6
„ acid	22	3	6

* Subject to rebate.

FINISHED STEEL

Usual district deliveries.

[A rebate of 15/- per ton for steel bars, sections, plates joists and hoops is obtainable in the home trade under certain conditions.]

	£	s.	d.
Plates, ship (N.E. Coast)	14	3	0
Boiler plts. (N.E. Coast)	15	0	6
Chequer plts. (N.E. Coast)	15	13	0
Angles, over 4 un. ins.	13	13	0
Tees, over 4 un. ins.	14	13	0
Joists, 3 in. × 3 in. and up	13	13	0
Rounds and squares, 3 in. to 5½ in.	14	13	0
Rounds under 3 in. to ⅜ in. (untested)	15	8	6
Flats—over 5 in. wide	13	18	0
„ 5 in. wide and under	15	8	6
Rails, heavy, f.o.t.	12	15	6
Hoops	16	3	6
Black sheets, 24 g. (4 t. lots)	19	7	6
Galv. cor. shts. („)	22	12	6
Galv. flat shts. („)	23	2	6
Galv. fencing wire, 8g. plain	24	7	6

FINISHED IRON

	£	s.	d.
CROWN IRON:			
England and Wales	15	2	6
Scotland	15	2	6
Ireland, f.o.q.	15	15	0
No. 3 BARS:			
England and Wales	12	5	0
Scotland	13	7	6
Ireland, f.o.q.	12	17	6
No. 4 BARS:			
England and Wales	12	15	0
Scotland	13	12	6
Ireland, f.o.q.	13	7	6
STRIP:			
England and Wales	16	10	0
STAFFS MARKED BARS, f.o.t.	18	0	0

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated, June 27, 1940.

	Dols.
No. 2 foundry, Phila.	24.84
No. 2 foundry, Valley	23.00
No. 2 foundry, Birm.	19.38
Basic, Valley	22.50
Malleable, Valley	23.00
Grey forge, Valley	22.50
Ferro-mang., seaboard	100.00
O.-h. rails, h'y, at mill	40.00
Billets	34.00
Sheet bars	34.00
Wire rods	2.00
	Cents.
Iron bars, Chicago	2.25
Steel bars	2.15
Tank, plates	2.10
Beams, etc.	2.10
Skelp, grooved steel	1.90
Steel strip	2.10
Steel sheets	2.10
Sheets, galv., No. 24	3.50
Wire nails	2.55
Plain wire	2.60
Tinplates, 100-lb. box	$5.00

COKE (at ovens)

Welsh foundry	42/6 to 44/-
„ furnace	31/6 to 33/-
Durham foundry	39/6
„ furnace	33/5
Scottish foundry	42/6 to 47/6
„ furnace	31/6

TINPLATES

f.o.b. Bristol Channel ports

I.C. cokes	20 × 14 per box		27/6 to 28/-
„	28 × 20	„	55/- to 56/-
„	20 × 10	„	40/- to 42/-
„	18¾ × 14	„	30/-
C.W.	20 × 14	„	27/6
„	28 × 20	„	55/-
„	20 × 10	„	40/-
„	18¾ × 14	„	29/-

NON-FERROUS SCRAP
(Official Maximum Prices, per ton ex Works.)

	£	s.	d.
Bright untinned copper wire, in crucible form or in hanks	57	10	0
No. 1 copper wire	57	0	0
No. 2 copper wire	55	10	0
Copper firebox plates, cut up	57	10	0
Clear untinned copper, cut up	56	10	0
Braziery copper	53	10	0
Q.F. process and shell-case brass, 70/30 quality, free from primers	49	0	0
Clean fired 303 S.A. cartridge cases	47	0	0
70/30 turnings, clean and baled	43	0	0
Brass swarf, clean, free from iron and commercially dry	34	10	0
New brass rod ends, 60/40 quality	38	10	0
Hot stampings and fuse metal, 60/40 quality	38	10	0
Admiralty gunmetal, 88-10-2, containing not more than ½ per cent. lead or 3 per cent. zinc, or less than 9½ per cent. tin	72	0	0

NEW BRASS TUBES, etc.

	Per lb.
Solid drawn tubes	13½d.
Brazed tubes	15½d.
Rods, drawn	11½d.
Rods, extd. or rlld.	8½d.
Sheets to 10 w.g.	10½d.
Wire	10½d.
Rolled metal	9½d.
Yellow metal rods	8½d.

COPPER TUBES, etc.

Solid drawn tubes	14½d.
Brazed tubes	14½d.
Wire	9½d.

PHOSPHOR BRONZE

	Per lb. basis
Strip	13½d.
Sheet to 10 w.g.	13½d.
Wire	15½d.
Rods	15½d.
Tubes	20½d.
Castings	17d.

Delivery 3 cwt. free.
10% phos. cop. £35 above B.S.
15% phos. cop. £40 above B.S.
Phosphor tin (5%) £40 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

AVERAGE MONTHLY PRICES OF CLEVELAND No. 3 PIG-IRON.*

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1900	67 10	68 10	73 10	76 2	74 2	68 6	69 3	71 4	70 9	67 8	63 6	58 6	68 9
1901	48 0	46 6	45 8	45 5	45 10	44 7	44 6	45 3	45 3	45 3	43 6	43 1	45 3
1902	43 11	46 7	46 9	47 11	48 10	49 7	50 9	52 1	53 6	52 9	50 9	47 11	49 3
1903	47 3	48 9	51 10	49 0	46 1	46 2	46 7	46 8	45 7	43 6	42 10	41 11	46 4
1904	42 3	42 7	43 3	44 7	44 0	42 10	42 9	43 3	43 1	43 9	46 1	48 7	43 11
1905	48 11	48 0	49 6	50 1	51 5	45 6	45 9	47 5	48 8	52 11	52 9	53 3	49 6
1906	53 9	50 1	48 1	48 8	50 2	50 3	50 6	53 0	54 6	56 8	58 6	62 4	53 6
1907	60 4	56 6	54 10	56 0	61 1	58 1	57 8	57 8	55 7	54 8	50 8	50 0	56 2
1908	48 5	49 3	51 7	51 10	51 6	51 2	50 0	51 4	52 0	49 8	49 4	46 11	50 8
1909	48 10	48 1	46 9	47 9	48 4	48 9	48 6	50 5	51 3	51 11	51 2	50 7	49 4
1910	51 10	51 3½	51 7½	50 10	49 10	49 2	48 10	49 8½	49 3½	49 7½	49 6½	49 10	50 4
1911	49 11½	49 2½	48 5	48 11	48 4	48 6	48 11½	47 4	47 0	46 7	47 4½	48 1	47 7
1912	50 0	49 5½	51 1½	53 7½	54 4	55 1	57 5½	64 6½	61 7½	66 8½	67 8	68 0	58 8½
1913	66 11½	63 8½	64 8	67 1½	66 3	66 9½	66 3½	65 8	65 4	63 0	60 1	60 4	64 10
1914	60 11	61 5½	61 0½	61 4½	61 6	61 6½	61 5	62 3	61 5	60 1	60 3	58 0	61 4½
1915	55 7	56 6	61 0	66 7	65 2	66 10	65 4	66 0½	65 3	65 11	69 10½	75 7½	65 7
1916	80 2	91 6	87 4½	86 10	82 6	82 6	87 6	87 6	87 6	87 6	87 6	87 6	85 10
1917	87 6	87 6	87 6	92 6	92 6	92 6	92 6	92 6	92 6	92 6	92 6	95 0	90 3
1918	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0
1919	95 0	95 0	95 0	95 0	152 6	160 0	160 0	160 0	160 0	160 0	160 0	160 0	137 8
1920	175 0	175 0	187 6	200 0	208 0	217 6	217 6	221 0	225 0	225 0	225 0	225 0	209 3
1921	222 6	195 0	150 0	126 0	120 0	120 0	120 0	136 3	127 0	120 0	110 0	100 0	137 4
1922	92 6	90 0	90 0	90 0	90 0	90 0	89 0	87 3	92 6	92 6	92 6	91 0	90 7½
1923	94 6	108 9	125 6	129 4½	123 5	136 0	128 1½	121 11	97 1½	97 0	100 0	100 0	110 6½
1924	99 10	97 3½	91 9	93 9	91 9	89 10½	87 9	85 0	82 5½	80 2½	81 9	81 0	88 7½
1925	80 4½	78 10½	78 0	78 3	76 0	73 10½	71 7½	69 10½	68 1½	66 7½	66 0	66 0½	72 10½
1926	69 4½	70 0	70 0	70 0	72 6	75 10½	86 7½	90 0	93 10½	117 10	120 0	99 0	86 3
1927	85 0	83 1½	81 0	80 0	73 9	70 0	70 0	68 9	67 6	67 6	66 10½	64 0	73 2½
1928	65 6	65 0	65 6	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0	64 0	65 9½
1929	66 0	66 9	67 0	68 1½	69 5	71 10½	72 9	72 6	72 6	72 6	72 6	72 6	70 4½
1930	72 6	72 6	70 0	67 6	67 6	67 6	67 6	64 6	63 6	63 6	63 6	63 6	66 11½
1931	59 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 7
1932	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6
1933	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6
1934	62 6	65 0	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	66 10½
1935	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	69 4½	70 0	67 10½
1936	70 0	70 0	70 0	70 0	70 0	70 0	75 0	75 0	75 0	75 0	75 0	81 0	72 0
1937	81 0	81 0	81 0	81 0	81 0	81 0	101 0	101 0	101 0	101 0	106 0	106 0	91 10
1938	109 0	109 0	109 0	109 0	109 0	109 0	109 0	109 0	109 0	109 0	109 0	109 0	109 0
1939	99 0	99 0	99 0	99 0	99 0	99 0	99 0	99 0	99 0	99 0	108 0	108 0	100 6
1940	108 0	111 0	111 0	111 0	111 0	111 0	—	—	—	—	—	—	—

* Delivered Middlesbrough area for years 1933 and onwards. Prior to 1933, prices were f.o.t. furnaces. NOTE: Prices have been subject to a rebate of 5/- per ton since November 1, 1937.

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